ILLUMINATING ENGINEERING

JUNE 1951

Low-Brightness Illumination for Newspaper Plant
Thermionic Cathodes for Fluorescent Lamps
Directional Lighting for Dental Clinics
Relighting Canadian Industrial Plant
Connecticut Fights Night Accidents
Dimming of Cold Cathode Tubing
Lighting of Control Rooms
Illumination Recorder

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

Another Co-ordinated Classroom

lighted with Wakefield *fluorescent* Stars

Room 18
OTTAWA HILLS
ELEMENTARY SCHOOL,
Ottawa Hills, Toledo, Ohio

Wakefield STARS were recently installed in 6 new and 10 existing classrooms in Ottawa Hills Elementary School. Room 18 shown here has a functional layout for daytime use only; note omission of row by windows.

THE STAR has a translucent Plaskon reflector which completely shields the fluorescent lamps. When the lamps are lit the reflector and the ceiling above it are of approximately equal brightness. This is a basic requirement of supplementary lighting systems for co-ordinated classrooms.

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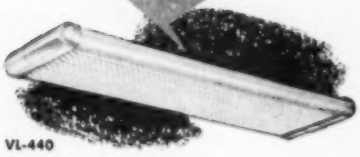

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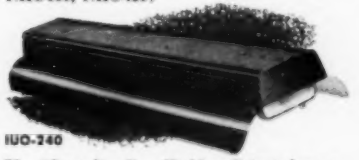

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ILLUMINATING ENGINEERING

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Relighting Canadian Industrial Plant

IN TAKING the photograph above, and the picture at right, showing the same area in Plant No. 2 of the Ford Motor Company of Canada, Windsor, Ontario, all conditions were held constant except light level. Care was taken to make the two pictures photographically comparable.

One, of course, shows the improvement in lighting accomplished in the south craneway of the plant after the installation of 3-kw high intensity mercury lamps in industrial luminaires. Spacing of the units is on 20′ x 21′ centers, with a mounting height of 35 feet. Resulting illumination is 75 ft-c inside, 85 ft-c center, 60 ft-c outside, at the windows.

The original installation, shown in the "before" picture at right, used 400-watt mercury vapor units in highbay equipment. Official information on the illumination level is not available, but it is believed to be of the order of 15 to 20 footcandles.

Before and after the relighting of the south craneway of Plant No. 2 of Ford Motor Company of Canada, Windsor, Ontario. The new installation features 3-kw mercury lighting.

Photograph and data supplied by T. A. Tame, I.E.S. Local Representative in Windsor, Ontario, Canada.

Low-Brightness Illumination for a Newspaper Plant

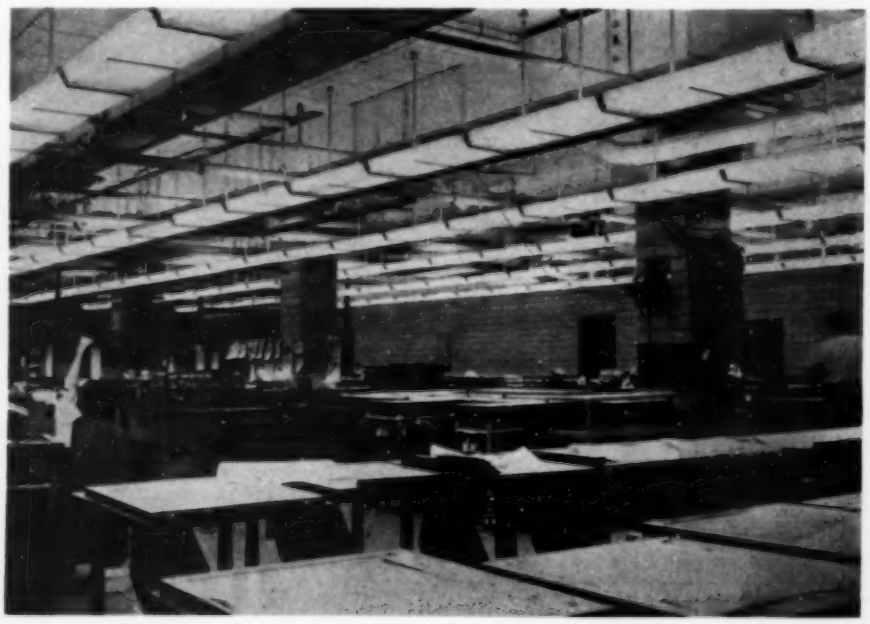
A HIGH visibility quality of illumination, with minimum maintenance, was the objective of the lighting planned for the new newspaper plant of the *Courier Journal and Louisville Times*, at Louisville, Kentucky. Low brightness, and the avoidance of harsh shadows was especially important to achieve high visibility of the type face.

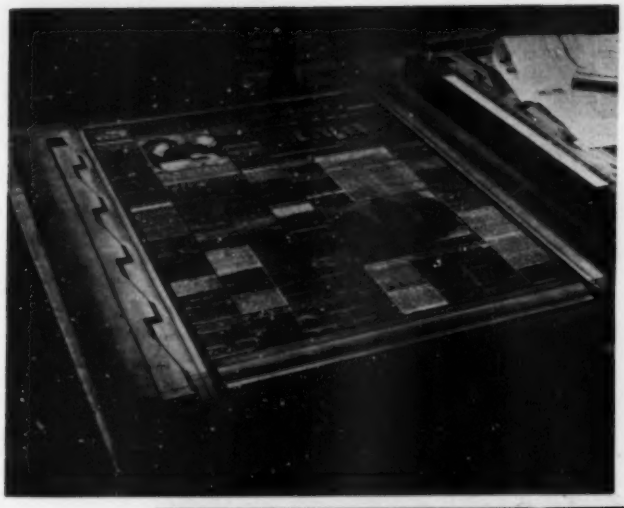
In the composing room, shown below, semi-indirect fluorescent lighting has been employed in continuous rows on 8-foot 4-inch centers. The ceiling in this room is considerably obstructed by pipes, beams and ducts. Such a condition might generally indicate direct industrial fluorescent luminaires as the best solution. However, the requirement of high visibility of type called for a large-area low-brightness light source. These requirements governed the decision to use semi-indirect equipment, and to paint white the ceiling and all duets and pipes. Each luminaire uses four 40-watt fluorescent lamps, which are shielded by side and bottom panels of enameled ribbed glass.

A close-up illustrating the appearance of the type on the stone is shown in the photograph at upper right. The room has been appraised by the compositors as "just the right kind of light for our work."

Photographs and data were supplied by W. H. Kahler, Westinghouse Electric Corp., Cleveland, Ohio.

Composing room of the *Courier Journal and Louisville Times*. Note how ceiling obstructions have been overcome.





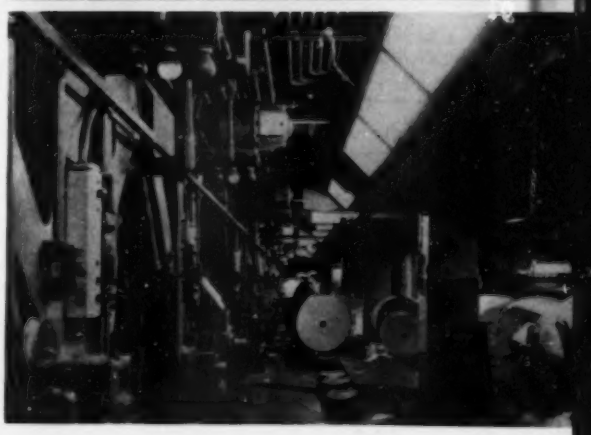
Close-up showing the appearance of the type on the stone, with semi-indirect fluorescent lighting. Quality in illumination is equally important with quantity in lighting here, to eliminate harsh shadows.

Illumination for the press room, shown in the center photograph at right, utilizes continuous rows of vapor-tight, totally-enclosed luminaires mounted on both sides of the press. Vapor-tight units were used to protect the lamps and reflectors from the ink mist and other forms of dirt accumulation. Approximately 40 footcandles of well-diffused illumination are maintained on the press, providing excellent visibility inside the press as well as along the sides.

Continuous rows of two-lamp 40-watt vapor-tight and dust-tight luminaires are also used in the reel room, shown in the photograph at lower right. These are mounted along both sides of the press, and tilted to illuminate effectively the mechanical and electrical components from floor to ceiling. Totally-enclosed units were selected to minimize maintenance.

Lighting for the general areas of the reel room is from two-lamp 40-watt industrial fluorescent luminaires with porcelain enameled, closed-end reflectors.

Continuous rows of vapor-tight luminaires are used to protect the lamps and reflectors from ink mist and other forms of dirt accumulation in the press room. Illumination here is 40 footcandles, well-diffused.



Continuous rows of two-lamp, 40-watt fluorescent lamps in vapor-tight, dust-tight luminaires are mounted along both sides of the press, and tilted to illuminate effectively mechanical and electrical components from floor to ceiling in the reel room.

Light and Agriculture

By J. P. DITCHMAN

AMERICAN agriculture is big business. By any standards of measurement its aggregates of production and employment make it the number one industry. More people are engaged in it than the next ten largest industries combined. The market value of its physical assets is greater than the total value of all stocks listed on the New York stock exchange. More significantly it is the bulwark of American institutions. Big as it is, its typical unit, the family farm, is today, as it was in 1776, the keystone of free enterprise.

The farm population is now only 17 per cent of the total and yet it provides all the food for our increasing population. Research in the mechanization of agricultural processes together with progress in plant and animal breeding has greatly reduced the number of people in the farming business. In 1945 each farm worker produced enough agricultural products to support himself and more than thirteen other people.[1] In 1920 when the farm population was about 30 per cent of the total, one farmer was able to support himself and nine other people. Back in the year 1800 one farmer was able to produce only a little more than enough food for himself or three other persons.

Today researches in radiant energy have offered the farmer such important new knowledge in the way light figures in the growth process of plants and animals, crops are now on the verge of being substantially removed from many previous uncertainties. Light has obviously released the farmer of the limitations of daylight hours for many of his most important jobs.

The advent of new artificial light sources stimulates the efforts of plant physiologists and other scientists to solve the fundamental riddle of how plants grow. Carbon arc incandescent lamps, sodium lamps, mercury lamps and many combinations of these have been used in growth chambers where light, humidity, temperature, and air are controlled to grow plants entirely under artificial conditions. Today laboratories are being equipped with combinations of fluorescent and incandescent lamps for this purpose. The illustration shows one such room at the Plant Industry Station of the United States Department of Agriculture in Beltsville, Maryland, equipped with 8-foot slimline lamps operating at 300 ma, supplemented by regular filament lamps. To get sufficient intensity (1000-2000 ft-c) to grow plants, the lamps are placed together as close as possible and enough air conditioning is provided not only to give the plants proper atmosphere but also to maintain the maximum output of the lamps.

By experiment it was found that the 4500° white fluorescent lamp was most satisfactory. However, this lamp must be supplemented with incandescent light to provide best growth. Absorption spectrum of chlorophyll indicates that light of all wavelengths throughout the visible spectrum can be used for the process of photosynthesis. However, it has two maximum absorption bands, one centering at about 4500 Angstrom units in the blue and the other at about 6500 Angstrom units in the red.

Photosynthesis

Photosynthesis is the interaction of radiant energy with organic phenomena which sustains life on our planet. Photosynthesis therefore is the basic process upon which all farming depends and even after all these many years of research it is still not well understood.[2] One cannot conceive of life existing on the earth were it not for plant life. So far as is known, green plants alone are able to produce proteins, fats, and sugars from stable inorganic materials by means of sunlight.

There are many laboratories in agricultural colleges equipped with rooms for growing plants entirely under artificial conditions, trying to develop methods independent of natural conditions. These research objectives, it is said, could lead (if successful) to political and economic consequences which could rival those of the atomic bomb. If we could maintain food production under ground, we could provide a hedge against some of the spectacular devastation feared in an atomic war.

Photoperiodism

There are many light-response reactions of plants with which most people are familiar. The bending towards light of common house plants, elongated shoots of potatoes in darkened cellars,

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: General Electric Company, Nela Park Cleveland, Ohio.

Figure 1. Marion Parker, Physiologist, and Harry Borthwick, Senior Botanist, Division of Fruit and Vegetable Crops and Diseases in their controlled environment laboratory at the Plant Industry Station of the United States Department of Agriculture in Beltsville, Maryland. The room is 10 ft x 20 ft with a 7½ ft ceiling. There are 106 4500° white T-8 slimline lamps and 24 100-watt filament lamps used in this installation to produce about 2000 ft-c.

At this level and with the spectral energy, provided by this particular combination of sources, it has been possible to develop relative growth data on a variety of vegetables. Growth records in general under the laboratory conditions are reported excellent. Detailed data are also developing valuable evidence as to individual plant response. (Photo by Riess.)

orientation of leaves and leaf cells under different intensities of light but the most interesting is the photoperiodic response of plants.[3]

Thirty years ago, two scientists of the United States Department of Agriculture, W. W. Garner and H. A. Allard, were given the job of getting tobacco plants to flower and produce seeds in the latitude of Washington, D. C. They submitted the tobacco to all known factors that govern the growth of plants. After considerable research, they discovered that the length of darkness and light in each 24 hours regulates the flowering of this variety of tobacco. Tobacco is a plant that requires a fairly short day to produce flowers. The area around Washington provided too long a day. When the plants were removed from the light and placed in the dark from 4:00 p.m. to 9:00 p.m. daily, they blossomed and produced seed.[4]

In many other kinds of plants as well, they discovered the fundamental law of nature which can tell us why some plants blossom in spring others in the summer or fall in some specific zones and not in others. This knowledge of the day-length need of various plants has been of great value in adapting the varieties of plants to needs of various sections of the country. Today plants are classified as short-day plants or long-day plants. There is a third day-neutral group, so called because they flower whether the day length is relatively long or short. One of the most common examples of photoperiodism is displayed by the chrysanthemum. It will not bloom until fall because the day lengths earlier in the season are too long. It blooms in the fall when the day lengths are short. Today the florist controls the time of blooming of the chrysanthemums and certain other flowers by regulating the day length in his green houses and thus times his harvest for special holiday markets. To do this, he darkens the plant with light-tight covers if the days are too long or he illuminates it for a time at night when the days are too short. The actual day-length varies with each variety.

Light requirements for this process vary with each plant but are not excessive: 0.1 to 50 foot-candles can be provided by filament or fluorescent lamp installations.[5, 6] Experiments have shown that the leaf of the plant is the part that is sensitive to day length. It was found that all wavelengths in the visible spectrum influence flowering but a region in the red is especially effective.[7]

This discovery of photoperiodism represented a distinct departure from the once prevalent idea that intensity of illumination was the principal factor concerned in the determination of the characteristic growth of flowering and fruiting of plants. This newer concept placed emphasis principally on the influence of successive rhythmic occurrences of light and dark periods and the relative length of such periods rather than on the light intensity alone.

It was further found that the formation of bulbs, tubers, thickened roots, production of pigments, and the initiation of dormancy are in a large measure controlled by the daily duration of light. It has since been learned that many kinds of plants are much more sensitive to photoperiodic conditions when grown at certain temperatures than at others. Harry Borthwick and Marion Parker of the United States Department of Agriculture are

continuing studies of photoperiodism in plant growth. They have conducted experiments that indicate that the effects taking place in the dark period are primarily responsible for the control of flowering both long-day and short-day plants.[7] The significance of the dark period in the regulation of flowering is demonstrated by the effectiveness with which the radiation for a short time in the middle of the dark period prevents flowering of short-day plants or causes flowering of long-day plants. The photoperiodic effect of interrupting the dark period for a few minutes to an hour near its middle is similar to the effect produced when light is used continuously to extend the natural photoperiod. Not only does this result in a reduction of the cost of light, but often the plant and flowers produced are commercially superior to those grown with extended periods of artificial illumination. For example, chrysanthemum growers now find that a brief dark-period interruption near the middle of the night delays flowering as effectively as does several hours of supplemental lighting applied immediately following or preceding the natural photoperiod. They find that the plants subjected to dark-period interruptions do not elongate so much and the flowers form more dense clusters. This makes them more acceptable to the trade.[8]

By manipulation of day lengths, it is possible to grow onions from seed to seed without the occurrence of bulb formation. The sex of hemp plants may be controlled by photoperiodism, thus helping control the amount and quality of the fiber obtained. Tests are under way in Hawaii to control the flowering of sugar cane by dark-period interruptions with resultant increased yield of sugar per acre.

Those who grow poinsettias in their houses sometimes have no flowers on them at Christmas because they are not aware of the fact that artificial light they use in the evenings and to which the plants are exposed makes the dark period so brief that the flowering of the poinsettia is impossible. They can readily avoid this cause of lack of flowering by placing the plants in darkness at about 6:00 p.m. and return them to light at about 8:00 a.m. daily. Dark-period interruptions applied to long-day plants will under certain circumstances promote flowering.[9]

The filament lamp, taking all factors into account, is the most satisfactory light source for day-length control. The lamps are inexpensive, small indimension, and made in a wide range of wattages. The 150-watt and 300-watt R-40 reflector flood lamps are commonly used for this type of applicacation. The fluorescent lamp equipments being large and bulky tend to cause considerable shading of the valuable natural light.

Rooting, Cutting, and Germinating Seeds

The propagation of rooted cuttings entirely under artificial light is practical with intensities from 150-200 footcandles, from 3500°K or 4500°K white fluorescent lamps. Photoperiods from 15-18 hours have given good results with nursery stock. These closed structures with no windows lend themselves well to the control of humidity as well as light.

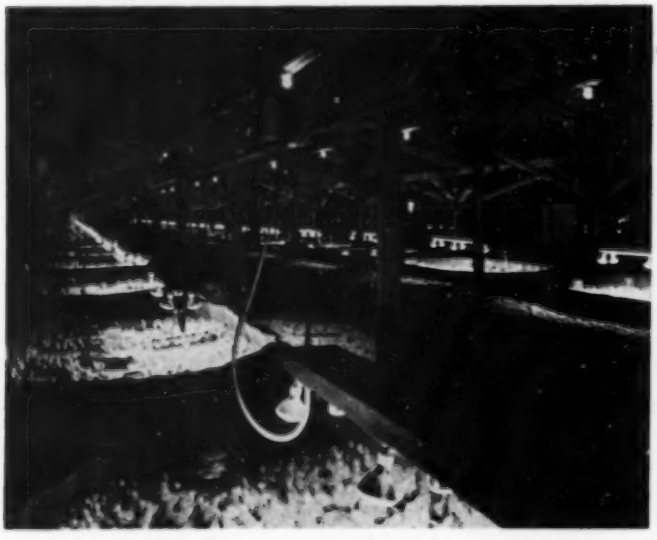


Figure 2. An outstanding application of infrared energy for providing warmth for 20,000 chickens. Four crops of broilers per year are raised from just-hatched baby chicks in this large 50 ft x 300 ft structure at Millsboro, Delaware. Each of the 38 units is equipped with 6 250-watt R40 infrared lamps. The complete installation of 228 lamps is connected to a voltage regulator which automatically maintains the proper energy level throughout the period of growth.

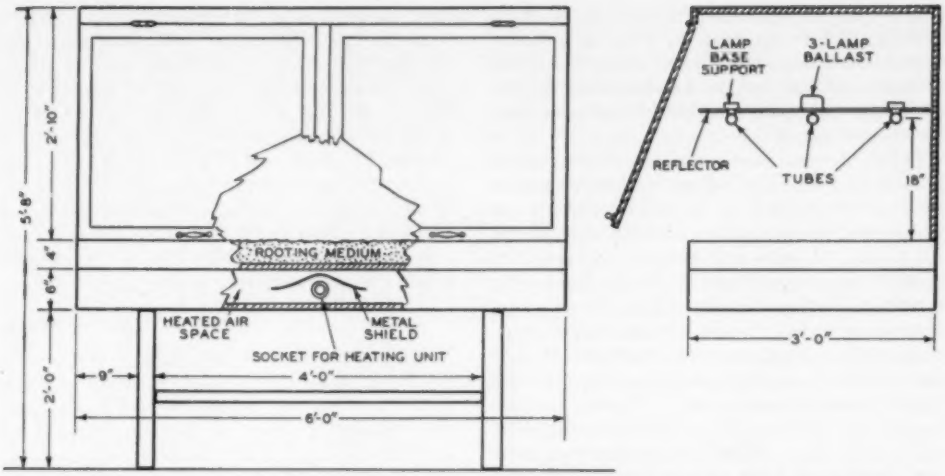


Figure 3. Diagram of unit used for propagation of cuttings and seed germination entirely under artificial light. (Redrawn from Stoutemeyer and Close[10] and Withrow.[5])

Seedlings can be started in these opaque boxes but higher intensities of light—600-800 footcandles—are desirable.[5, 10]

L. H. Flint[11, 12] studying light sensitivity in relation to dormancy in lettuce seeds found that on the order of 1000 footcandle-minutes was the minimum amount of light that would insure practically complete germination of dormant lettuce seeds at 68° F. The light was found to be most effective after the seeds had been soaked in water for several hours. At these levels, it was found that an exposure of a few seconds to direct sunlight was sufficient to meet the requirement of seed germination while seeds kept in the dark gave no germination. It has long been recognized in a general way that light exerted an influence on the germination of certain seeds but it has not been appreciated that th reaction to light is as rapid and as definite or essential to the germination as has now been found for lettuce seeds. The very rapidity of the action of the light appears to have led to its being inadequately recognized as an agent promoting the germination of many seeds.

H. H. Laude of Kansas Experiment Station[13] observed a daily cycle of heat resistance particularly corn, wheat, barley, sorghum, and alfalfa. The daily maximum resistance to heat was attained by plants at about midday and continued during the afternoon. The minimum resistance prevailed early in the morning. Resistance to heat increases when plants are exposed to light and decreases in the absence of light. One hour of light following normal darkness of night was long enough for plants to acquire a measurable and in some cases a marked resistance to heat. Ordinarily plants reach their daily maximum heat resistance within the four hours after exposure to daylight during the night. The loss of heat resistance in plants when exposed to darkness was slower than gain of resistance in the presence of light.

Effects of Light on Animals

In the animal field researches similar to that conducted on plants have been made. In 1893, H. Weiske[14] who conducted experiments on the effect of light on animal organisms found that light acts as a stimulant on the metabolism of the animal organisms and is manifested particularly by the fact that man and animal with otherwise identical conditions of nourishment produce more carbonic acid in the light than in the dark. Keeping, breeding, and feeding farm animals especially draft animals and milch cows which demand an active metabolism, it is best to give them all the light they want, but when beasts are to be quickly fattened for slaughter, it is unquestionably advantageous to depress metabolism and thus provoke the formation of fat and obtain greater weight with the same feed by shutting out the light.

An important but theoretically unexplained difference is known to exist in the composition of morning and evening dairy cow milk.[15] Besides the difference of fat percentage, there is also a difference in the amount of milk yield at morning and evening milking. The morning yield tends to be higher while its fat and other solid percentages

tend to be lower than the evening yield. It is interesting to note also that the morning milk has more bacteria than the evening milk. The proof of these rhythms can be substantiated by test where the life cycles are inverted in controlled environment rooms.

T. H. Bissonnette showed that the winter prime pelt of mink may be induced in the summer in spite of the relatively high temperatures or hastened in the autumn by reducing durations of the periods of light and intensity to which the animals are exposed daily.[16] Today fur-bearing animals are being subjected to light controls on a commercial scale. Tests are being conducted on such animals as sheep and goats which normally have limited breeding seasons. Results are very encouraging to those who wish to extend the breeding season of goats and sheep by controlling light cycles.[17]

Studies made at Cornell University along these lines indicate that the fertility level of herds of cattle can be correlated with the monthly average length of daylight. It is concluded from their research that the variation in the hours of daylight influence the fertility level of dairy cattle at the latitude of Ithaca, New York. The response to light varies with the age of the animals involved.[18]

Growth development studies of domestic animals are being conducted at the University of Missouri. They have investigated the diurnal rhythms of metabolism and other activities. The inter-relations between these rhythms increase the difficulties of interpreting any data taken on the effects of radiation on animals and plants. A small difference may be the result of a diurnal or another type of activity rhythm rather than the factor under investigation.[18]

Humans are subject to many such rhythms, for example, the reaction time of normal man to light and sound is lowest in the morning when the body temperature is lower.

Poultry Lighting

The writing of Marcus Cato in 116 B.C.[19] indicates they too knew of these light phenomena. In raising poultry, which they all did in those days, it was the practice to confine the birds in darkened shelters and many times break their legs and wings to immobilize them so that they would grow fat. If they wanted to stimulate metabolism they would force them out into the sunshine whenever the weather was mild for they knew that they grew strong and healthy by so doing.

It was thought that by providing light for chickens 13 or 14 hours a day, the chickens ate more, drank more, and therefore laid more eggs. However, it was found that the light had a definite effect on the chickens, it stimulates its reproductive organs and as a result the chicken laid more eggs and therefore ate more and drank more. Further tests conducted at the University of Minnesota in 1939 showed that this stimulation was the result of energy entering the eye.[20] These effects were prevented in most birds by blindfolding during the period when the extra light was supplied. The use of light in poultry houses to stimulate egg-laying during the winter months when daylight is limited and production is normally low is the common practice on the commercial poultry farm today.

Effects of Light on Insects

Nothing is known of the sensation that insects experience when they see either colored or white light. Therefore any intimation that insects have color perception should be avoided. There is no question that light is of extreme importance to insects as indicated by the size and the development of their compound eyes. Their eyes have large receptors in comparison with the volume of the comparatively less developed central nervous system. There have been many conflicts in this field of insect color vision because results were described in terms of human color vision.[21, 22]

G. S. Fraenkel, in his book, *Orientation of Animals*,[23] discusses many of the movements of insects towards or away from light sources. Literature on this subject is very fascinating because it shows that every conceivable variation of radiant energy, spectral distribution, orientation, quantity, duration, intensity, etc., may have some action on the insects or animals. Just to mention one of these with which we are familiar, the effectiveness of the light source in attracting nocturnal insects. Researches in this field have indicated that most nocturnal insects have receivers that are sensitive to the blue and the ultraviolet part of the spectrum. This is being used to particular advantage in agricultural fields where sources of ultraviolet and visible blue are being used to attract the cornborer moth to its destruction. The BL (fluorescent black light) lamp has been so attractive in tests conducted during the last few years that the ordinary high-voltage traps being used to electrocute the moths have been clogged by the tremendous flight of the insects. Light traps are being used as indicators to give the farmer fair warning when he should use control measures against the flight of this particular pest.[24]

A by-product of these researches has resulted in increased use of yellow lamps for outdoor lighting. Yellow lamps provide a minimum amount of energy to which the insect is sensitive and a maximum to which the human eye is sensitive.

W. R. Miles of Yale University[25] has recently revealed experiments which indicate that roaches and bees detect odors by means of electromagnetic radiation in the infrared region. Perhaps the most fantastic tests indicating the sensitivities of insects were conducted by Professor Miles when he released seven males of a rare moth species from a train at intervals 1 mile apart. Within hours all seven had found the female of the species who was at that time in a hermetically sealed tube.

R. C. Dickson of the University of California last year reported that he was able to induce diapause in the oriental fruit moth by daily exposures to light during the larva-feeding period. Diapause is a physiological state of arrested development which enables an organism to survive more easily a period of unfavorable conditions. He points out that larvae in the absence of light do not enter diapause. However, if the periods of light per day are increased, the percentage of diapause increases reaching about 100 per cent with about 12 hours of light per day.[26]

Other Effects of Light

There are many other reactions of light radiation on animals and humans. The most familiar of these of course, is the erythema or reddening of the skin, tanning of the skin, the germicidal action of sunlight, elevation of blood pressure in sunlight, formation of Vitamin D in the skin. Some of the lesser known effects are interesting. For example, if one infects animals experimentally, keeping one group of animals in the dark, another in the light, the latter will be more resistant to the infection.

Radiation of the skin stimulates individuals making them more active and desirous of moving about. When the abdomen of a frog is stimulated by light even though the eyes are not illuminated, they will react reflexly and accommodate themselves to light. This reflex is not the result of neural action but is due to a substance which arises in the skin under the influence of light and is carried by the blood to the organs. This can be proved by transfusing the blood from a frog kept in a lighted room to one which has been kept in the dark whereupon the latter's eyes also exhibit accommodating reaction. Fritz Kahn, in his book, *Man in Structure and Function*, calls this substance a light hormone. It increases the functional capacity of the muscles and sense organs. If a man in a dimly illuminated room is shown several gray plates and at the same time light is directed upon his uncovered legs, the plates will appear lighter to him. Similarly his auditory acuity will also be increased. A person exposed to light hears, sees, and acts better than one who is in the dark.

Light and Fish

Many aquatic animals which normally swim horizontally with dorsal surfaces upward, maintain their orientation optically by keeping perpendicular to the light which passes through the surface of the water.[28] Experiments with certain fish indicate that when they pass from one aquarium which has light on the top to one that has light on the bottom, the fish automatically invert themselves and swim upside down.

A recent paper by C. W. Coates and J. W. Atz, New York Aquarium, New York Zoological Society,[27] shows the importance of proper orientation of light in connection with lighting public aquariums. He pointed out that light sources located at the front and top of the aquarium did not affect the fish adversely. However, if the lamps are located at both ends of the glass-sided aquarium, with the light shining through the water horizontally directly at the fish, the appearance might be very delightful to the visitors but to the fish it may be disastrous. He has found no species ever tested has thrived under such lighting conditions. Most of them have died quite soon. It would seem that the fish's nervous system is conditioned to light coming only from above, they are unable to cope with any drastic changes in light direction. Fluorescent lamps have been used in lighting aquariums very successfully from the standpoint of display and from the standpoint of the fish. Both fish and aquatic plants grow very well, except that the direction of light must be correct.

Summary

When one realizes that minute intensities of light may be adequate to affect plants in regard to their blooming time, it becomes important to study environments carefully so that floodlighting and electric signs do not upset some of these delicate balances. Just recently an electric sign put on top of a green house, interrupted the dark cycle of the poinsettia plants inside. The grower was lucky that it was discovered in time so that he was able to meet the Christmas trade. Another example and more serious was the case of a floodlighting installation made in the vicinity of a mink ranch which completely upset the breeding cycle of the mink.

Many claims have been made on the effectiveness of so-called sunlamps, germicidal lamps, and infrared lamps that were attributed to the ultraviolet or infrared energy emitted by those sources. It must be borne in mind that other radiations are emitted by these lamps which may play an important part in the results. The author recalls one experience in this field where due to poor voltage

conditions, measurements showed complete absence of ultraviolet and yet splendid results were obtained from sunlamps.

It has not been the purpose of this paper to list as fully as case history makes possible, the examples which show how widely light and radiant energy may be applied to problems of plant and animal life. What has been covered here will suffice to show that the counsel of our profession is required in more and more different fields.

It should be expected as our experience broadens that we be prepared to extend what we know about familiar problems to the newer, less familiar ones. Most of us naturally think of lighting in terms of human uses. Our most frequently used instrument of measurement, the light meter, is calibrated for human values. Therefore it is to be hoped that one will keep in mind the specific energy distributions relevant to plant and animal life when one has a problem in these fields. The problems in all cases must be approached with respect for the point of view of the plant or animal.

Our world may in the future depend very much upon how well we learn how to apply radiant energy to produce more and better food, and to reduce the life processes which oppose our own.

Acknowledgments

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Reprints of "Contemporary Lighting for Modern and Traditional Interiors"

Attractively bound copies of the complete I.E.S. Study Report, "Contemporary Lighting in Modern and Traditional Interiors," reprinted from ILLUMINATING ENGINEERING, and now in its second printing, are available for distribution in single copies or quantities. This 60-page publication covers the entire field of contemporary residential lighting and is an ideal lighting reference for architects, home lighting specialists and consultants, interior decorators and contractors. Light and power companies, manufacturers of residential fixtures and portables will find it an excellent promotion piece for their preferred lists which include these customers. Single copies up to 10 are priced at $1.00; quantity prices upon request.

Lighting a Jewelry Store

LIGHTING OBJECTIVE: To provide general illumination and highlight merchandise.

Installation at Claude S. Bennett, Inc., 207 Peachtree Street, N. E., Atlanta, Georgia; architect: Boyce W. Pearson; contractor: Brooks-Allison Co.; lighting engineer: T. Taylor Peake, Georgia Power Co., all of Atlanta.

General Information: The room is divided into two sections: the front is 18 feet long and 19 feet wide with a 13½-foot ceiling; rear is 50 feet x 19 feet x 16 feet. Walls are pale green (50% RF), ceiling is white (80% RF), wall and display cases are light birch (35% RF), and the carpet is blue-gray (15% RF).

Installation: In the front area are installed eight 300-watt filament counter lights (Holophane F-1814) and four flush-mounted luminaires (Holophane 9102-4) each containing three 40-watt 4500K

(over)

A.I.A. File No. 31/14

fluorescent lamps. The rear is illuminated by twenty-two 300-watt filament counter lights (Holophane E-1814) and eighteen surface-mounted units (Holophane 9112) with four 40-watt 4500K fluorescent lamps each. All luminaires have glass control lenses. Counter lights are oriented to highlight merchandise in the display cases.

Resultant illumination levels are as follows:

Counter top, front of store	
Counter lights only	90 ft-c
General lighting only	50 ft-c
Counter top, side of "horseshoe," center of store	
Counter lights only	70 ft-c
General lighting only	80 ft-c

Brightnesses measure:

Display Cases (illuminated by ceiling-mounted counter lights)	15 ft-L
Wall Cases (lighted with 40-watt 4500K fluorescent strip)	10 ft-L
Wall (3½ feet below ceiling)	10 ft-L
Ceiling (1½ feet from wall)	10 ft-L
Luminaires	
Along axis 45° vertical	
9102-4	1235 ft-L
9111	1455 ft-L
E-1814	815 ft-L
F-1814	815 ft-L
Across axis 45° vertical	
9102-4	981 ft-L
9111	1161 ft-L
E-1814	620 ft-L
F-1814	620 ft-L

Lighting data submited by Judd Lough, Holophane Company, Atlanta, Georgia as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society
1860 Broadway, New York 23, N. Y.

Connecticut Fights Night Accidents

A report prepared by the Street and Highway Lighting Committee of the Connecticut Section, Illuminating Engineering Society

SEVERAL years ago, Richard E. Simpson, under the auspices of the Connecticut War Production Board to Conserve Manpower, published one of his very interesting and informative papers giving the results of an intensive study of street and highway fatalities in ten Connecticut cities during the preceding fifteen years. This paper presented facts and figures which showed not only that a far greater number of traffic fatalities happen at night, but also that a large majority of all traffic fatalities in these ten cities occurred on certain particularly heavily traveled thoroughfares, appropriately referred to as "Connecticut's Fatal Streets."

With the lifting of restrictions at the end of the war, it was possible to proceed with the long overdue relighting of some of these thoroughfares. During the past year, a new study has been made of accident experience on some of these same streets in order to determine to what extent their relighting has been able to alter their "fatal" designation. The results of this investigation are submitted here as simple evidence of the fact that adequate street lighting can and does contribute materially to the reduction of street and highway accidents at night.

The new study covered the following main traffic streets in six Connecticut cities: Albany Avenue, Hartford; Dixwell Avenue, New Haven; Watertown Avenue, Waterbury; Stanley Street, New Britain; Groton-New London Bridge, New London; Summer Street, Stamford. All figures were calculated on the basis of one year's experience before and after relighting, except in the case of Hartford, where data were available for three years before and after. Accident records were taken from the files of the State Motor Vehicle Department; traffic volume was obtained either by personal observation and count, or from city and State Highway Department records. Both property damage and personal injury accidents were included.

Although the statistics for the six streets varied widely due to different traffic densities and other local conditions, in all important respects they exhibit the same general trend toward improved safety after new lighting was installed. The accompanying charts show the results for all six streets taken as a group.

Fig. 1 represents the traffic volume, in million vehicle miles both day and night, before and after relighting. Day and night traffic increased about 24 per cent and 29 per cent respectively, after relighting, indicating the general increased use of motor vehicles and also the preference on the part of motorists for driving on well-lighted streets. The figures also show that approximately 29 per cent of the total traffic volume, both before and after relighting, occurs at night, while about 71 per cent of the traffic moves in the daytime.

The total accident experience on these six streets during the periods under consideration is shown by Fig. 2. The number of day accidents increased after relighting, following the general trend of the

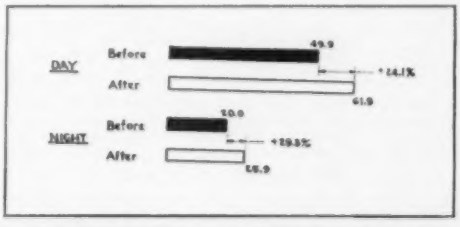


Figure 1. Traffic volume in million vehicle miles.

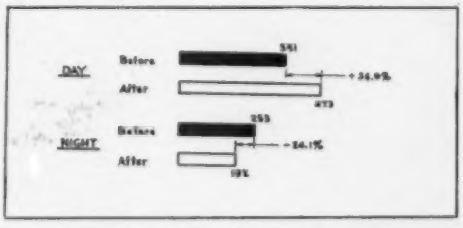


Figure 2. Total number of accidents.

Authors: R. E. Simpson, Consulting Engineer, Fellow, I.E.S., and R. S. Newhall, Street Lighting Engineer, the Connecticut Light and Power Co. Both Mr. Simpson and Mr. Newhall are members of the Sub-Committee on Public Lighting and Traffic Safety of the Street and Highway Lighting Committee, I.E.S.

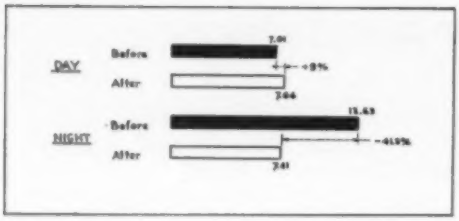


Figure 3. Accidents per million vehicle miles.

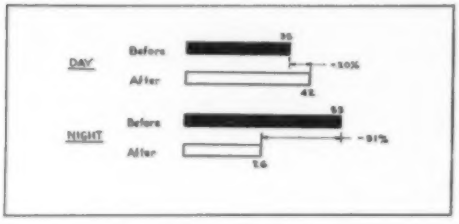
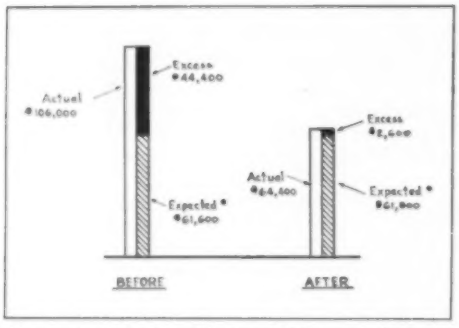


Figure 4. Pedestrian accidents.



*The amount which night accidents would have cost if the ratio of night-to-total accidents had maintained the same relationship as night-to-total traffic volume.

Figure 5. Night accident costs.

increased traffic volume. The number of night accidents, however, was reduced by 24 per cent in spite of the increase in night traffic volume.

The sharp reduction in night accidents after relighting is even more apparent when allowance is made for the difference between day and night traffic volume. In Fig. 3 it is seen that there was a slight increase in the number of accidents per million vehicle miles in the daytime, but a considerable reduction in the number of night accidents per unit of traffic volume.

Except for impaired visibility at night, there is no particular reason why the number of night accidents per unit of traffic volume should exceed the number of day accidents. In fact, on the basis of traffic volume, we should expect something less than one third of the accidents to occur at night, since night volume (Fig. 1) is only about 29 per cent of the total. Before these six streets were relighted, however, we find from Fig. 2 that 253 accidents, or 42 per cent of the total, happened at night. Under improved street lighting, the number of night accidents dropped to 192, or 29 per cent of the total, indicating that night traffic, *under adequate lighting*, need be no more hazardous than day traffic. This fact is further confirmed in Fig. 3, which shows that after the installation of improved lighting, the number of accidents per million vehicle miles was about the same both night and day.

One of the most important benefits of relighting these streets has been the reduction in the number of pedestrian accidents, as shown by Fig. 4. Here again, although the daytime pedestrian accidents increased in direct proportion to the traffic volume, night pedestrian mishaps were just about halved when the streets were relighted. This again emphasizes the need for good street lighting to shorten the odds of the uneven battle between pedestrian and motor vehicle, in which the comparatively slow

Summer Street in Stamford, Conn., is lighted by luminaires with 6000-lumen series lamps, mounted on poles approximately 30 feet to light center on 75-foot staggered spacing.

Dixwell Avenue, New Haven, Conn., has luminaires mounted approximately 25 feet to light center, staggered on 115-120 feet.

Thirty-foot wide Stanley Street, New Britain, Conn., uses 6000-lumen filament lamps, mounted at one side at 110-125 foot spacing and 25-foot height.

and tremendously outweighed pedestrian is invariably the tragic loser.

Carrying this study a step further, figures were developed to show the economic saving to the communities through the reduction of night accidents on these six streets. In order to arrive at dollar values, the costs of property damage accidents were taken from the reports of persons involved. After investigation of a large number of cases, personal injury costs were assumed at $400 per injury, a figure which is known to be low and which does not include court costs.

In the period following relighting, the total cost of all day accidents kept pace with the increased traffic volume, showing a rise of 26 per cent. During this same period, however, the cost of night accidents was reduced by 39 per cent due largely to the decrease in the number of night accidents. Considering property damage accidents alone, we find that, before relighting, the average cost of night accidents was 58 per cent higher than day accidents. After relighting, the average night accident was 5 per cent less expensive than a day accident, indicating a marked drop in the severity of night accidents when visibility is improved.

Perhaps the most significant fact to come out of this study is the sharp reduction in what might be referred to as the "excess cost" of night accidents after these streets were relighted. As was pointed out above in discussing the relationship between traffic volume and accident experience, the number of night accidents before relighting far exceeded the number which might have been expected, considering the smaller volume of night traffic. Similarly, the cost of night accidents is out of all proportion to the night traffic volume.

If conditions were the same both day and night, we could assume that the cost of night accidents would bear the same ratio to the total cost of all accidents as the night traffic volume bears to the total traffic volume. Thus it is possible to arrive at a "normal" or "expected" figure for night accident costs. Excess cost, then, is the amount by which the actual cost exceeds this expected figure.

Fig. 5 shows how the actual night accident costs before and after relighting compared with the expected costs on these six streets. Before adequate lighting was installed, the actual cost of night accidents was $106,000, or $44,400 in excess of the expected amount. After relighting, the excess cost was reduced to $2,600, a drop of 94 per cent.

For the four streets on which cost figures were available, the annual increase in cost to the municipalities for street lighting improvements totaled $12,697. In one year after relighting, the total cost of night accidents on these streets was reduced by $13,393 below what it had been for the year before, thus realizing an immediate cash saving for the taxpayers of these communities. This again proves the statement that "you pay for good street lighting, whether you get it or not."

Thermionic Cathodes For Fluorescent Lamps and Their Behavior

By ERWIN F. LOWRY

COMPARED TO MANY present-day electronic devices the hot cathode fluorescent lamp and its associated equipment appears to be extremely simple. Actually, this very simplicity presents many problems of design not encountered in connection with electronic equipment which is operated in more orthodox fashion. This statement is particularly applicable to cathode design and operation.

The orthodox cathode of the oxide coated type such as used with most radio tubes is designed to furnish thermionic electron currents at least equal to the peak current the tube is expected to pass. It is heated uniformly to the optimum temperature at all times by a separate circuit. Seldom is it required to furnish full current before reaching proper operating temperature. In gas filled tubes special time delay relays are usually provided to prevent closing of the anode circuit before the cathode has come to full temperature. Seldom are such cathodes required to withstand appreciable electron bombardment.

It may be argued that cathodes subjected to pulsed emission requirements do not fulfill the first of these requirements. The actual operating time in these tubes is very short, however. Since each pulse is of only a few microseconds duration, such cathodes are required to furnish electrons usually much less than one per cent of the time. Figuring a tube life of a few thousands of hours, the actual operating life of the cathode is only of the order of 50 to 100 hours.

Mechanism of Cathode Operation

In the fluorescent lamp an entirely different situation must be faced.

1. Although for convenience these cathodes are referred to in the title as thermionic, the fluorescent lamp cathode does not furnish peak electron currents by thermionic means alone. Most of the lamp current is supplied by electrons removed from the cathode by reason of field emission, secondary emission and ion bombardment. Assuming well established thermionic constants, the cathode areas and temperatures concerned are entirely inadequate to explain the electron currents involved if thermionic emission alone is responsible. This lack of adequate thermionic emission would result in extremely short cathode life except for the presence of an appreciable amount of inert gas filling to protect the cathode. The use of argon at pressures of 3 mm of mercury or thereabouts as a fill gas has been found to be very effective. As mentioned elsewhere[1] this is one of the chief reasons why argon or some other inert gas is used in these lamps. This protective action of argon or other inert gas is equally important when "cold" cathodes are used and no thermionic emission is in question.

2. No separate heating of the cathode is provided. In a-c operation most of the cathode heating arises from electron bombardment during the half-cycle when the electrode is acting as anode. Some additional heating results from ion bombardment and from the I^2R losses in the tungsten wire core caused by the discharge current flowing in through the leads and out through the cathode surface during the other half cycle. In d-c operation only the latter sources of cathode heating are available. In either case the cathode heat developed is directly related to the arc current being drawn. Since the electron emission of a cathode is an exponential function of its temperature, this is in the right direction. However, when currents much less than those for which the cathode is designed are being drawn, the cathode heating available may be entirely inadequate.

The bombardment type of cathode heating ordinarily results in what is known as "hot spot" operation. Since points on the cathode will vary in potential depending on their distance from the live lead and since it is a practical impossibility to maintain all elementary areas of the cathode surface at exactly the same electron emitting efficiency, the discharge tends to localize at the most efficient emitting areas and also at areas nearest the live lead. The practical result is that this type of cathode does not operate at a uniform temperature throughout its length. A "hot spot" develops

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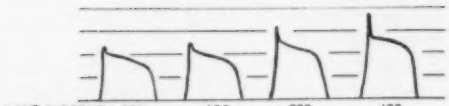
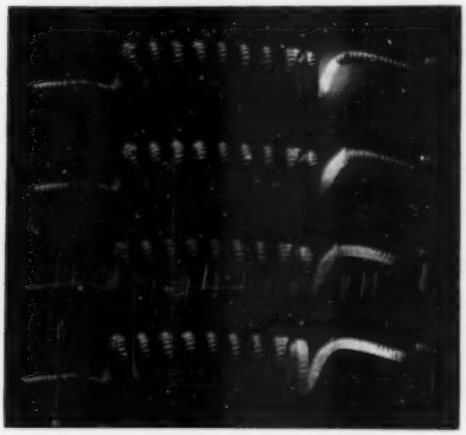


LAMP CURRENT	.600	.425	.200	.100
COIL TEMP °C	1030	990	925	910
COATING TEMP °C	1030	990	1100	1100+

Figure 1A. Graph showing the effect of lamp current on lamp voltage and cathode temperature for a 40-watt T12 lamp. The curves are oscillographic traces of lamp voltage.

Figure 1B. Photographs of 40-watt T12 lamp cathode operated at various currents. (a) (top) 100 ma, (b) 200 ma, (c) 425 ma, (d) 600 ma.



which comes to a temperature and area equilibrium depending on the arc current being passed.

Effects of Lamp Loading on Cathode Operation

If a change in area of the hot spot were the only variable resulting from change in arc current, no serious effect on lamp life or performance might appear but important changes in the temperature of the hot spot also accompany changes in lamp current. Along with these variables sizable changes in lamp voltage also appear. While some of this voltage change is due to variation in the potential gradient in the arc, some of it must be a change in the cathode fall of potential. Fig. 1 indicates what sort of changes in lamp voltage and in cathode temperature take place under these conditions.

Fig. 1A includes data obtained on the cathode of a 40-watt T12 lamp operated on a straight line variable reactor at four different currents. The curves of the figure are cathode ray oscillograph traces of lamp voltage at the respective current indicated immediately below each trace. The temperatures shown are brightness temperatures of the hottest spot on the cathode coil at these four currents and the corresponding brightness temperature of the cathode coating in the same cathode area.

In Fig. 1B are shown photographs of the cathode under the conditions outlined above. At 425 ma and at 600 ma it is difficult to distinguish between the temperatures of the tungsten and the coating. At 200 ma, however, and especially at 100 ma the tungsten is dark compared to the coating. At these low currents also the coating temperatures become unstable. The tiny incandescent areas are continually moving about over the coating surface. These areas are so small that accurate measurements of the temperature are very difficult. This inaccuracy is simply indicated in 1A by showing that the coating temperature at 100 ma is in excess of 1100°C.

Obviously, a certain amount of variation in lamp current is entirely permissible and results in no unfavorable performance. Nevertheless, any cathode operates best at some definite value of lamp current. A cathode which is properly designed for best operation at 400 ma, for example, will run too hot at 600 ma and entirely too cold at 100 ma. If such a cathode is operated at too high a current and temperature, excessive vaporization of barium will take place, discoloration in the form of anode spots will appear and lamp life will be materially shortened. In a recent paper[2] Thayer and Brownell have stated that in the vicinity of rated current each one per cent increase in lamp operating current will result in a two per cent reduction in lamp life. If the cathode is operated at too low a current, too high a percentage of the total emission must be obtained by ion bombardment, field emission, or some other mechanism than thermionic emission. This method of operation is conducive to an excessive cathode fall of potential, greatly increased cathode sputtering by ion bombardment, the formation of heavy end bands and, in extreme cases, very short life. Present day cathodes withstand fairly wide variations in lamp current rather well but sound engineering principles demand that for optimum performance the lamp should be operated at a given current and that current should be the one for which the cathode was designed.

The life of an oxide cathode in a gas discharge tube is terminated when the cathode coating is completely stripped from the metal core. In other words, the cathode coating is "expendable." However—other things being equal—the more coating a cathode contains, the longer will be its operating life. This statement should be qualified by limiting

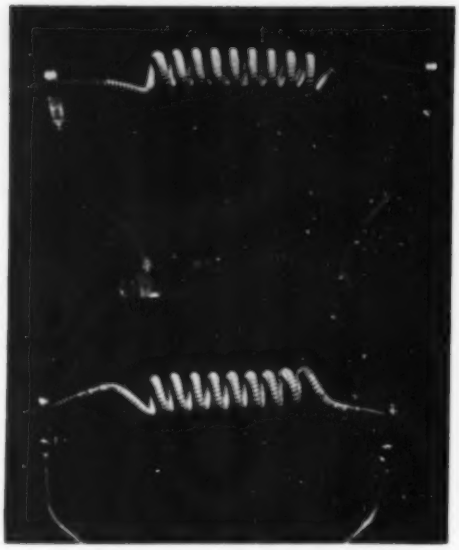


Figure 2. The cathode assembly for Sylvania 40-watt fluorescent lamps. (Top) The cathode before activation. (Bottom) The cathode after activation showing how the coating fills the turns of the primary coiling.

it to "effective coating" or coating which adheres closely to the core. The oxides of the alkaline earths do not have the same temperature coefficient of expansion as tungsten so it is not feasible to pile an unlimited amount of coating on to a given core structure.

It turns out that the cathode coating is most effective when it is held entirely within the turns of the primary coiling which should be completely filled with this material. Little, if any coating should be on the outside of the coil or bridging the turns of the secondary coiling.[3] Fig. 2.

The Function of "Anodes"

Some years ago, it was common practice to equip the cathodes of fluorescent lamps with "probes" or "anodes." As might be guessed they performed no useful function as cathodes. It was thought that they aided in lamp starting, as they possibly did, to some extent. Their main purpose was to absorb some of the electron current striking the electrode structure during the anode half-cycle and thus decrease the electron bombardment of the real cathode. They did just that. The amount of current absorbed by these probes varied depending on their size and positioning with respect to the cathode coil. Measurements show that they absorbed as much as one-third to one-half the lamp current in some cases.

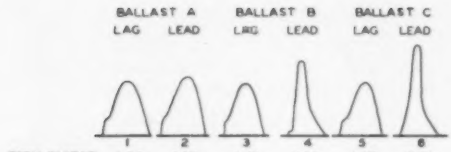
Since the principle source of cathode heating is this very electron bombardment, the use of probes seriously limited the size of cathode which could be brought to an efficient emitting temperature with a given lamp current. The elimination of these appendages has permitted the use of larger cathodes capable of holding efficiently considerably more emissive coating and giving correspondingly longer lamp life.

Two instances remain where probes are of value. In lamps operated on d-c the logical construction would be to have a cathode at one end and an anode at the other. For purposes of complete flexibility, however, it is more convenient to construct such lamps with similar electrodes at each end. In this case the addition of probes have little, if any, function at the cathode end other than aid in starting but do absorb much of the electron bombardment energy at the anode end and prevent overheating of the coated coil with the resulting end blackening by spot formation. Probes have continued to be used in lamps carrying currents of an ampere or more although even here tests now underway indicate that they may constitute excess baggage with properly designed cathodes and can be eliminated.

The Effect of Ballast Design

In common with all arc discharge devices the fluorescent lamp has a negative volt-ampere characteristic which means simply that the device itself has little or no control over the current it will pass. The current flowing through a fluorescent lamp is limited and controlled almost wholly by the auxiliary equipment. This statement applies as well to instantaneous values of the current as it does to the integrated or R.M.S. values. The immediate result of this situation is that the performance of the lamp is determined to a surprising extent by the electrical characteristics of the auxiliary with which it is associated. Not only must the auxiliary equipment provide the necessary open circuit voltage to start the lamp reliably but it should have the proper impedance and form factor to operate the lamp at rated current and wattage. Poor lamp performance is often directly related to ballast design and no fault of the lamp itself.

The requirements that the ballast should furnish adequate starting voltage and should hold R.M.S. values of lamp current within allowable limits are obvious. The third requirement regarding ballast form factor may not be so obvious but is equally important. Lamp life, lumen output and efficiency, and flicker are all affected by ballast characteris-



	1	2	3	4	5	6
FORM FACTOR	1.44	1.56	1.49	2.09	1.47	2.21
LAMP WATTS	37.9	39.5	37.8	34.2	37.9	35.6
LAMP CURRENT	.403	.419	.415	.405	.417	.448
LAMPS TESTED	3	3	3	3	6	6
FAILED 5000 HRS	NONE	NONE	NONE	2	NONE	6

Figure 3. Graph showing relation between ballast form factor and lamp behavior. 40-watt tu-lamp preheat ballasts and 40-watt lamps are compared.

ties. Usually the form factor of a transformer or transformer-choke combination is expressed in terms of peak to R.M.S. ratio.

The ideal form factor is that of a sine wave having a peak to R.M.S. ratio of 1.41 to 1. If a straight line reactor is used for ballast the current through the lamp will closely approximate a sine wave with a similar form factor. With many ballasts now available, the form factor does not approach this ideal. With some of them, indeed, the ratio of peak to R.M.S. currents through the lamp is more than 2.0 to 1.0. When such ballasts are used not only is the peak current which the cathode must furnish very high compared to the R.M.S. value but if the lamp is operated at rated wattage the R.M.S. value of current is also higher than it should be. The following curves and data of Fig. 3 show graphically the situation resulting from variations in form factor.

Three types of commercial dual lamp ballast for 40-watt preheat lamps were used in this test. Measurements of ballast characteristics were made at 118 volts line for each ballast, using reference lamps. These measurements included cathode ray tube studies of the form factor as shown in the illustration. Only the positive half of the wave for each type of ballast is shown since in all cases the positive and negative halves were quite symmetrical. All three types of ballast had very good form factors on the lag side. Ballast "A" also had a good form factor on the lead side but the ballasts of "B" and "C" type had peak to R.M.S. ratios in excess of 2.0 on the lead side with correspondingly low values of lamp wattage. In case of the "C" type ballasts the lead lamp wattage was very low even though the lamp current exceeded normal rating considerably.

After these measurements were made groups of 40-watt lamps were life tested on these ballasts with the results shown in the last two rows of data. Three ballasts of type "A," three of type "B," and six of type "C" were tested. After 5000 hours of operation on a three-hour cycle all the lamps on type "A" ballast were still burning as were all the lamps on the lag sides of "B" and "C" ballasts. On the lead side of the "B" ballasts, however, two of the three lamps had burned out at 4100 and 4850 hours respectively and *all* the lamps on the lead side of the "C" type ballasts had failed. These failures occurred between 2500 and 4250 hours. This test alone might represent too small a sampling to arrive at definite conclusions but the wide difference in behavior between the lamps on ballasts with good form factor where no failures occurred in 15 lamps at 5000 hours as against eight failures out of nine lamps burning on ballasts with a form factor of two to one or higher is at least worthy of serious consideration. Thousands of lamps operated on ballasts similar to "A" consistently have given average life expectancies in excess of 7500 hours, therefore, the life of the eight failed lamps which was an average of 3700 hours was about half that to be expected of the lamps burning on the ballasts with good form factor. This figure agrees very closely with results reported by Thayer (loc. cit.) who shows that lamps burning at a given wattage on ballasts with a 2:1 peak to R.M.S. ratio will have about 55 per cent the life of similar lamps operating at the same wattage with ballasts having a 1.5 to 1 peak to R.M.S. ratio.

From an inspection of Fig. 3, it is obvious that there are two important differences between the current curves 4 and 6 and the other four curves shown. These are:

1. Peak value of lamp current.
2. Steepness of wavefront $\frac{dI}{dt}$.

The peak current in the case of No. 6 for example is 150 per cent of the peak current for No. 2, whereas, the R.M.S. value is only 7 per cent greater than that of No. 2. The cathodes of the lamp operated on No. 6 ballast should have 50 per cent more electron emitting capacity than those for the lamp on No. 2. This excess emitting capacity can be secured only by a momentarily higher cathode voltage drop and increased ion bombardment velocity, resulting in more rapid cathode coating erosion.

During the half cycle when a given electrode is acting as anode, there is a drift of ions away from the electrode resulting in a decrease in ion density immediately surrounding the electrode except for such replenishment of ions as may be furnished by the electrode itself. If now the current is reversed as happens every half cycle and the anode now becomes cathode, there is a temporary lack of ions in the vicinity of the cathode necessary to neu-

tralize the electron space charge. Since ions have a finite mobility and that of mercury ions is low because of their large mass and particularly so because of the presence of argon atoms, the rate at which ion concentration about the cathode builds up is relatively slow. If the current wavefront is very steep as in No. 4 and No. 6, the rate at which the current increases may well exceed the rate at which the ion density is able to increase. The immediate result of this situation is an increased cathode drop until the ion density does reach adequate proportions. Such ions as are present will fall into the cathode with high velocities and lamp life will be correspondingly shortened.

Another lamp characteristic which is closely tied to ballast form factor is the stroboscopic effect or flicker. Variation in light emission follows closely lamp current, therefore, a high peak to R.M.S. current ratio results in a correspondingly high flicker effect. Tests which have been run at various times show that per cent flicker is closely proportional to the peak to R.M.S. ratio of the ballast involved. Although definite data cannot be presented at this time, there is evidence that form factor is associated with ballast hum and radio interference.

Photometric data on lamps operated with ballasts of poor form factor invariably show that the luminous efficiencies in lumens per watt of the lamps are slightly less than for the same lamps operated on ballasts with good form factor. The immediate result of this situation is that the lamps operated on the lead side of ballasts like type "C" of Fig. 3 will be much dimmer than those on the lag side. This is a serious defect in any installation using tu-lamp auxiliaries of this type and the more so because the dim lamps will also have a color difference resulting from their low loading.

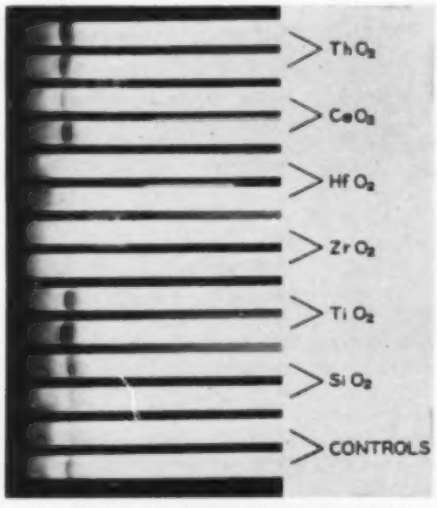


Figure 4. Photographs of lamps after burning 1000 hours. Cathode coatings contain the additives indicated.

In order to obtain optimum lamp performance in respect to life, light output, and flicker the auxiliary equipment should be designed to give a form factor as close as possible to that of a sine wave at rated current and wattage on both the lead and lag sides of the dual circuit.

The Effect of Cathode Coating Formulation on Lamp Life

As long as a lamp of any type has a depreciation in lumen output with operating time, there is no economic reason for it to have unlimited life. As a result of the intimate relation between efficiency, lumen maintenance, and life in the case of incandescent lamps, the most economical design life for these lamps is 750 to 1000 hours depending on size. There is no relation between design life and initial efficiency in the case of fluorescent lamps, nor do most of the things that affect life have any appreciable effect on lumen efficiency or lumen maintenance. However, normal depreciation in lumen efficiency results in an economic limit to lamp life. It turns out that the most economical life for a fluorescent lamp at average loading with the excellent lumen maintenance to be expected today is about 6000 hours.

With the cathode used for many years consisting of a tungsten coil coated with two or more of the alkaline earth carbonates, lamp life did not reach this optimum value. Rated lamp life was limited to 2500 hours, although the actual average life was somewhat longer, being about 4000 hours. Furthermore, end discoloration after two to three thousands of burning hours was usually such as to seriously impair the appearance of the lamp installation.

A long continued series of investigations were undertaken in our laboratories[4] to discover, if possible, a method of remedying this situation. Since both the end of life and the formation of discolored areas on the lamp wall were the result of cathode coating disintegration, one method of attack on this problem was to search for a cathode coating material which would better resist the destructive action of ion bombardment. Many variations in the proportions of the alkaline earth oxides were tested and many additives were incorporated in the coating. It was found that certain additives gave the desired result if added in the right proportions. Two in particular were very effective. They were the oxides of zirconium and

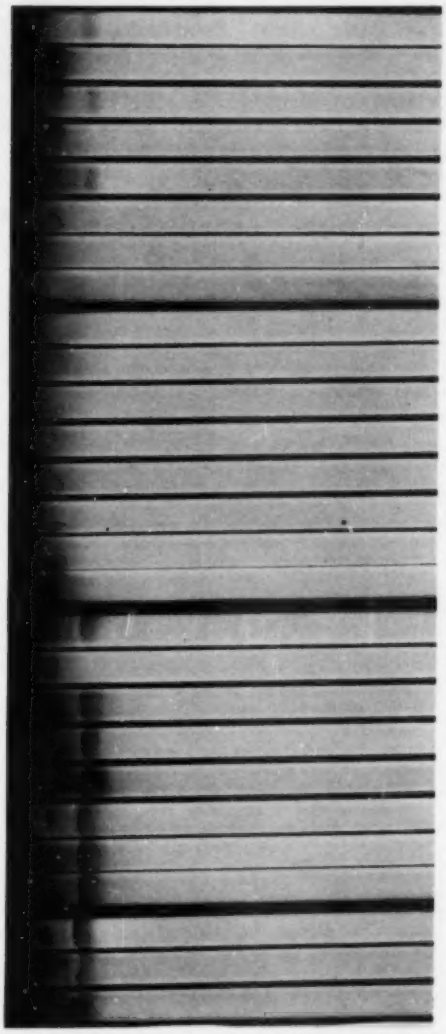


Figure 5. Photographs of end discoloration on lamps after 2700 hours burning. The cathode coatings contain various percentages of ZrO_2. Controls with no ZrO_2 at top.

hafnium. Some of the other additives tested in the course of this study simply diluted the coating. Others were definitely injurious. Fig. 4 illustrates the results obtained, as far as discoloration is concerned, in a test comparing the oxides of the various elements of Group IV. In this test the cathode coils had been previously oxidized to accelerate the discoloration. The marked improvement in discoloration when ZrO_2 and HfO_2 were used as additives is obvious. Comparing the amount of discoloration of lamps with standard coating as shown at the bottom of the photograph with those containing the various additives, it will be noted that SiO_2 has little, if any, effect while TiO_2, CeO_2 and ThO_2 actually appear to have accentuated the discoloration. Many similar tests were run, with corresponding results. Tests were run with the particle size of ZrO_2 varying from 0.2 micron to 2.0 microns and with ZrO_2 co-precipitated from zirconyl nitrate along with mixed crystals of the alkaline earth carbonates. Other tests were run varying the amount of ZrO_2 used in the cathode coating.

Fig. 5 illustrates the typical results obtained. In this test the amount of ZrO_2 was varied from 0 to 25 per cent. In the figure the 0 per cent or control lamps are shown at the top.

It turned out that the addition of ZrO_2 in proper percentages had an equally startling effect on lamp life. The results of all tests were so conclusive that this new cathode coating was put into production using about 5 per cent ZrO_2. Life test results on these production lamps bore out all predictions made from experimental results.

Fig. 6 is a bar graph showing the relative amount of end discoloration appearing after 1750 hours of burning on production lamps before use of this new coating and immediately after it was adopted. Each bar represents the average discoloration in arbitrary units for all lamps tested during an entire month.

Fig. 7 is a similar graph showing the improvement in lamp life resulting solely from the use of ZrO_2 in the cathode coating. Here each bar represents the average life of all lamps so tested from a month's production during the year immediately preceding and the year immediately following the adoption of this new coating. Without zirconia

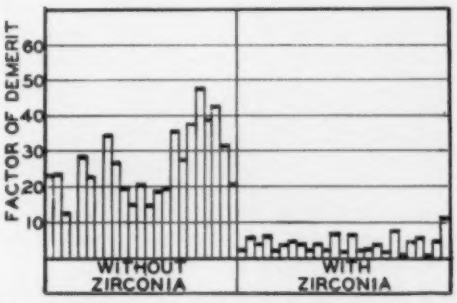


Figure 6. Bar graph of total discoloration on 40-watt production lamps after 1750 hours burning before and after use of cathode coatings containing ZrO_2.

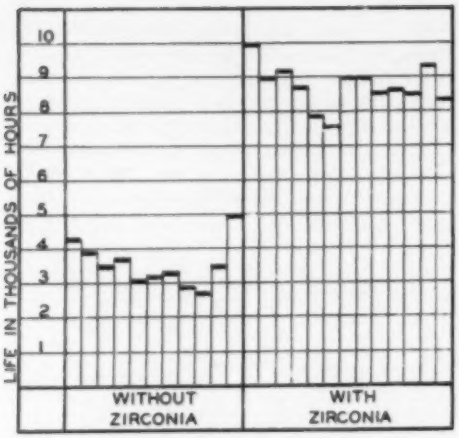


Figure 7. Graph showing increased life of 40-watt production lamps resulting from addition of ZrO_2 to the cathode coating.

additions, the average life of these lamps was about 3500 hours. With zinconia additions the average has been about 8500 hours. These data refer to lamps operated on preheat starting circuits but a similar improvement has been noted in the case of lamps operated on instant start circuits. The addition of ZrO_2 to the cathode coating more than doubles the life of the lamps on either type circuit and delays appreciably the formation of end discoloration. It must not be assumed, however, that this improved cathode coating is a panacea like the "Kickapoo Indian Remedy." Cathodes using this coating are still subject to the ill effects resulting from improper operation and poor form factor.

Summary

The fluorescent lamp cathode is heated primarily by electron bombardment during the anode half cycle. As a consequence its temperature and, therefore, its electron emission is a function of lamp current.

For optimum performance lamps should be operated at the current for which the cathode is designed.

Auxiliary "anodes" or "probes" are shown to be non-essential, except in certain specialized cases.

Lamp life and other characteristics are shown to be seriously affected by poor form factor of the ballasting equipment.

A new cathode coating is described which has more than doubled lamp life and materially reduced end discoloration.

Acknowledgments

The author wishes to express his indebtedness to various members of the Engineering Staff of the Lamp Division for the aid he has received in the preparation of this paper. Particularly, he desired to thank Mr. Eric L. Mager, Mr. Horace H. Homer, and Mr. A. Zack who have done much of the experimental work upon which this article is based.

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DISCUSSION

E. H. RADDIN*: This paper is typical of the previous excellent work Dr. Lowry has done in presenting fluorescent lamp development data to the I.E.S. membership. The information contained applies to a large percentage of that membership and brings out several very pertinent facts with which lighting engineers should be familiar.

We agree with the paper that the more coating applied to the cathodes the longer the life of fluorescent lamps. We have obtained good life with the cathode coating on the outside of the secondary coil, even to the extent of bridging the turns of the secondary coil with the coating. However, we find this extra coating does not adhere well and chips off; also manufacturing difficulties occur. Our practice conforms with that stated in the paper.

Concerning the use of "anodes" or "probes," we believe the information in the paper is sound and information from tests we have conducted seems to indicate that in most cases, probes can be eliminated.

We should like to emphasize the importance of Dr. Lowry's statement that improper ballast design is responsible for the lamp on the leading circuit operating at lower brightness than the one on the lagging circuit, being dimmer and appearing to be a different color. This has frequently led to consumers feeling that lamp colors vary when the trouble was actually in the ballast.

I am most interested that Dr. Lowry states that 6000 hours under proper operating conditions is the most economical life. We have been recommending that 7500-hour fluorescent lamps be replaced in a group at 6000 hours since our calculations, test as well as studies with many users, show this usually to be the most economical time for group replacement of fluorescent lamps in consideration of lamp labor, maintenance, and operating cost.

E. F. LOWRY**: It is gratifying to know that Mr. Raddin's experience so closely agrees with the statements set forth in this paper.

It seems impossible to emphasize too strongly that improper ballast design is responsible for the poor performance of many lamps. From several points of view, life, discoloration, light output and lamp color are definitely affected adversely if ballast form factor is not at least within ASA specifications.

*Champion Lamp Works.
**Author.

How to Design Your Luminous Ceilings

By PARRY MOON
DOMINA EBERLE SPENCER

Simplified methods are presented for the design of luminous-ceiling lighting. The number of lamps and the lamp spacing for a given illumination are found from tables, or a new slide rule is used to determine lamp spacing and brightness ratios.

LUMINOUS ceilings of diffusing plastic have been installed recently in a number of offices, drafting rooms, libraries, and school classrooms. This modern method of lighting is applicable also to stores, homes, and many other places where freedom from glare is important. A recent study shows that the light from a luminous ceiling produces excellent modeling, giving a true three-dimensional effect with pleasing gradations and transparent shadows. Thus museums, photographic studios, and television stations are possible users of luminous ceilings.

In view of the interest in the subject and its wide potentialities there is need for a simplified method of calculation. With a given number of lumens per square foot at table level, the spacing between rows of fluorescent lamps must be varied through a considerable range as the room shape and the reflectances are varied. The 3:1 brightness criterion can be satisfied only if the reflectances are high. The tables and slide rule described in this paper are based on the following average reflectances:

walls	50 per cent
floor	30 " "
furniture	30 " "
reflecting ceiling	80 " "
luminous ceiling (viewed from below)	70 " "

In addition it is assumed that no reflectors are used on the fluorescent lamps, and that the plastic has the highest possible transmittance that is consistent with complete diffusion. For other conditions the

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Figure 1. A school classroom in Newton, Mass., lighted by a luminous ceiling of diffusing plastic. This photograph was taken with the window shades drawn and with no other source of light than the ceiling. Note the transparent shadows and the absence of glare.

Figure 2. An office at Brown University. In this case, the existing ceiling beams were utilized and the luminous panels were fitted into the space between beams. The floor is of asphalt tile with reflectance 40 per cent and the walls are a pastel green with 50 per cent reflectance. The 3:1 criterion is satisfied except for the mahogany desk.

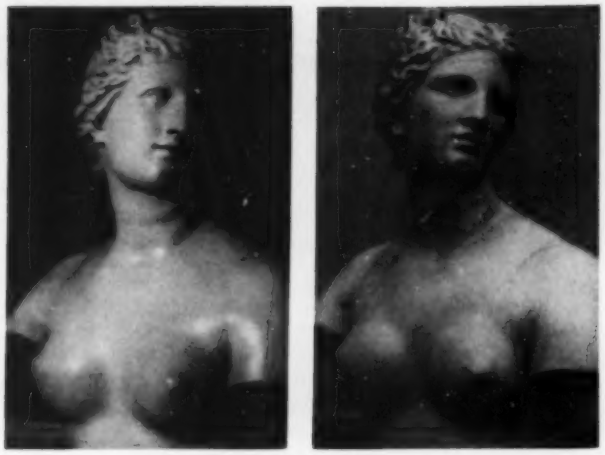

Figure 3. Luminous-ceiling lighting produces a pleasing three-dimensional effect. The harsh shadows in the photo far left are the result of using a single concentrated source. The other photograph was obtained under the same conditions, except that a luminous ceiling was the only source of light. Note the good modeling and the transparent shadows.

designer must use more general methods of calculation, such as the basic interflection tables.[3]

First consider the design of a luminous ceiling by means of standard tables. The procedure is as follows:

(1) Compute the room coefficient k_r which specifies the *shape of the room.*

$$k_r = \frac{(\text{height from floor to plastic}) \times (\text{room length} + \text{room width})}{2 \times \text{length} \times \text{width}}$$

(2) Find the normal spacing s between rows of fluorescent lamps (Table I). Distance from outside rows to the walls can be made approximately equal to s/2, or the $\frac{3}{4}$ s - $\frac{1}{4}$ s arrangement can be used.[1]

(3) Determine *distance from lamps to diffusing plastic.* This distance must never be less than two-thirds the spacing between rows of lamps.

Example

A luminous ceiling is to be employed in lighting a room 28 x 40 feet, the distance from floor to plastic being 10 feet.

(1) The room coefficient $k_r = 0.30$.

(2) From Table I, spacing is given as 42.1 inches, with 75-watt T-12 3500K fluorescent lamps. Evidently 5 lamps can be used per row in the 40-foot direction. For a 42-inch spacing between rows (center to center) there will be

$$\frac{28 \times 12}{42} = 8 \text{ rows of lamps.}$$

Therefore,

Total lamps = 40

Total power = 40 (75 + 14) = 3560 watts
(using 2-lamp ballasts with 28 watts total loss per ballast)

Watts per square foot = 3.2

Normal spacing, s = 42 inches

Distance from lamps to side walls = 21 inches

Initial illumination will be 100 lumens per square foot, as indicated in Table I. Illumination in service is obtained by multiplying the initial value by a maintenance factor.[2] Any other value of illumination can be obtained by increasing or decreasing the number of lamps in proportion to the illumination. For example, to get 200 lumens per square foot in this room, use 80 lamps instead of 40. To get 50 lumens per square foot, use 20 lamps instead of 40.

(3) The distance from lamp centers to plastic must be at least $\frac{2}{3}$ of the spacing between lamps. Therefore, in this design the plastic must be hung at least *28 inches below the lamps.* Violation of this requirement will give a spotty appearance to the ceiling. If sufficient height is not available above the plastic, the distance between lamps must be

TABLE I.—Spacing Between Rows of Fluorescent Lamps To Give 100 Lumens per Square Foot (Initial Illumination).

k_r	A	B		
		150 ma	200 ma	300 ma
0	61.1 in.	9.3 in.	42.6 in.	53.2 in.
0.1	53.7	25.7	37.4	46.7
0.2	47.5	22.7	33.0	41.3
0.3	42.1	20.3	29.3	36.7
0.4	37.6	18.0	26.2	32.6
0.5	33.5	16.1	23.3	29.2
0.6	30.0	14.4	20.8	26.2
0.7	26.9	12.8	18.7	23.3
0.8	24.0	11.6	16.7	20.9
0.9	21.6	10.3	15.0	18.9
1.0	19.3	9.3	13.4	16.9

A = T-12 slimline 96", 75-watt; or T-12, 48", 40-watt lamp.
B = T-8 slimline, either 72" or 96".
All lamps 3500K.

TABLE II.—Brightness Ratios.

For best visual conditions, brightness ratios should not exceed 3. The table gives values for ceiling, walls, and floor compared to a 65 per cent reflectance horizontal task at desk level (taken such that ratio is always greater than 1).

k_r	Ceiling	Walls	Floor
0	1.54	2.00	2.17
0.1	1.71	1.96	2.24
0.2	1.89	1.92	2.32
0.3	2.10	1.87	2.40
0.4	2.33	1.82	2.48
0.5	2.59	1.77	2.57
0.6	2.89	1.72	2.66
0.7	3.20	1.67	2.75
0.8	3.55	1.63	2.85
0.9	3.98	1.58	2.95
1.0	4.41	1.53	3.05

Based on luminous ceilings with 70 per cent over-all luminaire efficiency and the following reflectances: reflecting ceiling 80 per cent, luminous ceiling as viewed from below 70 per cent, walls 50 per cent, floor 30 per cent.

reduced. For example, if only 14 inches is available, use T-8 lamps (Table I) at 120 ma with about 21 inches spacing between lamps. This arrangement would again give 100 lumens per square foot but would result in a more expensive installation because of the larger number of ballasts and the additional wiring.

Brightness Ratios

Whether an ideal visual environment is produced or not depends largely upon the brightness distribution in the field of view. The brightest surface should not exceed 3 times the value to which the eyes are adapted, and the adaptation value should not be more than 3 times the lowest brightness in the visual field.

Table II gives brightness ratios for ceiling, walls, and floor, all referred to adaptation to printed matter (average reflectance 0.65) on a horizontal surface at desk level. Note that the 3:1 criterion is satisfied by luminous-ceiling lighting in all rooms with low k_r, but for k_r above 0.7 there is a tendency for the ceiling to be too bright and the floor too dark. This tendency can be counteracted by further increase in reflectances.[3]

The data of Table II are for the recommended wall reflectance of 0.50 and floor reflectance of 0.30. If the actual reflectances are lower than these values or if the plastic is not thoroughly diffusing, ceiling lighting cannot make the room ideal visually.

The Calculator

All the information contained in Tables I and II can be incorporated in a simple calculator. One form is shown in Fig. 4. To use the calculator, proceed as follows:

(1) Obtain k_r by calculation.

(2) Move slide of calculator until arrow marked "k_r" points to value obtained in (1).

(3) Read (from top scale) the spacing between rows of fluorescent lamps. This spacing will give *100 lumens per square foot* (initial value), using either the 75-watt T-12 (96-inch) or the 40-watt T-12 (48-inch) 3500K fluorescent lamps in continuous rows across the ceiling.

(4) The lower window of the calculator allows the designer to see if the 3:1 criterion is satisfied.

(5) Distance between lamps and plastic should not be less than $\frac{2}{3}$ of the spacing between rows of lamps.

(6) Ceiling above the plastic must be pure white (reflectance at least 80 per cent). Walls must have an average reflectance of at least 50 per cent. Floor and furniture must have an average reflectance of at least 30 per cent.

(7) If the 72-inch or the 96-inch T-8 3500K fluorescent lamp is used instead of the 75-watt lamp, multiply the lamp spacings (read from the calculator) by

0.48 for 120 ma,
0.70 for 200 ma,
0.87 for 300 ma

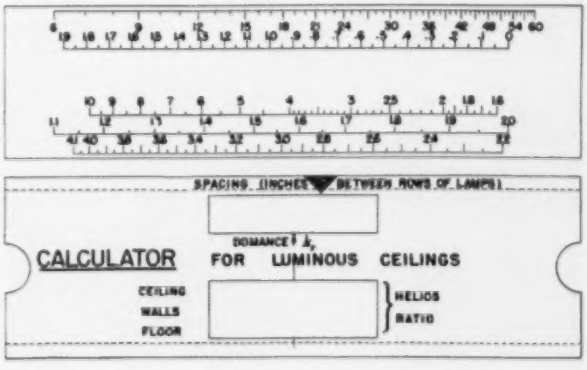

Figure 4. A calculator for luminous-ceiling lighting. The upper part of the drawing shows the slide. This slide moves behind the two windows of the stationary part of the rule, the front of which is shown in the lower part of the drawing. (Note: domance equals room coefficient; helios ratio equals brightness ratio referred to a 65 per cent reflectance task on horizontal surface at desk level.

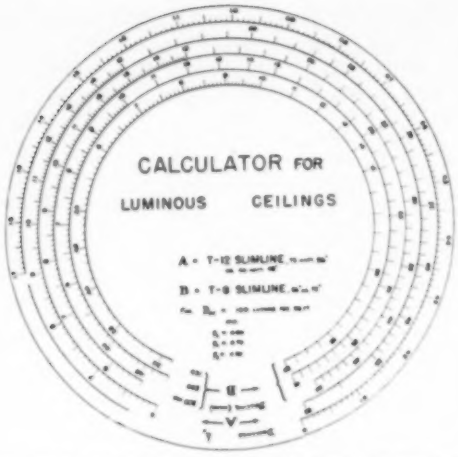

Figure 5. A circular calculator which shows the spacing to be used with various lamps. A transparent plastic indicator (not shown) is pivoted at the center of the device and carries a hair line.

Example

A drafting room 8 x 60 x 120 feet is to be lighted by means of a luminous ceiling. The calculator, Fig. 4, is used in the design.

(1) From computation, $k_r = 0.10$.

(2) and (3) Move the slide until the k_r-arrow points to 0.10, and read (from the upper scale) the spacing of 53.7 inches. Since this is an awkward value, choose a more convenient one, for example, 48 inches. Then if continuous rows of 75-watt lamps are run in the 120-foot direction (15 lamps per row), there will be 60/4 = 15 rows.

Thus,

Total number of lamps = 225

Total watts = 225 (75 + 14) = 20,000

Watts per square foot = 2.8

Normal spacing = 48 inches

Distance between lamps and side walls = 24 in.

(4) The brightness ratios from the lower window of the calculator are

Ceiling	1.7
Walls	2.0
Floor	2.2

which shows that the 3:1 criterion is satisfied.

(5) Distance between lamps and plastic must be at least $48 \times \frac{2}{3} = 32$ inches. If this space is not available, the number of lamps must be increased.

In the foregoing design, the average illumination (initial value) would have been 100 lumens per square foot if the lamp spacing had been 53.7 inches. Decreasing the spacing to 48 inches increases the initial illumination to

$$100 \times \frac{53.7}{48} = 112 \text{ lumens per sq. ft.}$$

References

1. Moon and Spencer: "Luminous-Ceiling Lighting," ILLUMINATING ENGINEERING, Vol. XLIV, No. 8, p. 465 (August 1949).

2. *Lighting Design* (Chap. VII), Addison-Wesley Press, Cambridge, Mass. (1948).

3. Ibid., Chaps. V and VI.

4. "Simplified Interflection Calculations," to be published in the *Journal of the Franklin Institute* (1951).

5. "Modeling with Light," to be published in the *Journal of the Franklin Institute*.

ILLUMINATION LEVELS of several hundred footcandles are required for many critical seeing tasks at the Woodward Governor Company in Rockford, Illinois. Localized lighting, carefully located, with light sources shielded from workers' eyes is means used for providing these high levels. Good general lighting from overhead luminaires must be supplied to avoid surrounding contrast. Light finishes on other luminaire surfaces are highly desirable.

Bulb Sizes for Incandescent Filament Lamps

By W. E. ANDERSON

The change in bulb sizes used for general lighting incandescent electric lamps since the advent of tungsten filaments is reviewed. The basic principles governing their design; how developments on filament shapes and gases have permitted reduction in size without sacrifice in service performance; and how fixtures have been an important factor in the final determinations, all are presented as contributing to the present day smaller lamp dimensions.

THE TREND towards higher illumination levels has been virtually axiomatic since man built his first bonfire and lighted his first torch. It did not take him long to find out that the more torches he had, the greater the area over which he could see, and that the larger his torch, the more easily he could see the smaller things in his immediate vicinity. Thus was born the "Better Light-Better Sight" principle now actively promoted by our illumination engineers.

It is now almost a half century since the tungsten filament lamp was born. Recognition of the approach of its fiftieth birthday may therefore appropriately be combined with a mid-century review of its development, especially in reference to the size of the bulbs used in general lighting lamps.

Instead of growing larger with age, the reverse has been true in respect to the tungsten filament lamps. The trend has been toward smaller bulbs for standard wattage ratings and towards higher wattage in bulbs previously standard for lower wattage lamps. Both, in effect, increase the illumination levels from fixtures that limit the physical dimensions of the lamp which they can accommodate. Combined with simultaneous research and development to increase lamp efficiencies, this trend has produced significant changes. The outline drawings and dimensions shown in Figs. 1 and 2 indicate the degree to which the changes have progressed.

That the trend towards smaller bulbs has contributed to an increase in illumination levels is confirmed by surveys which show that the average watts consumed per lamp socket has increased from less than fifty in 1915 to more than eighty in 1949.

Before discussing the latest changes, a review of the basic principles governing the choice of bulb for the various wattage lamps may be in order. The term "bulb" as used above and in our subsequent discussion is limited to the glass envelope containing the filament and the filament supporting structure, as distinct from the lamp. The "lamp" is the complete light producing unit including bulb and base; the "fixture" is the light distributing unit, namely, the shade, reflector or diffusing globe inclusive of the socket and wiring but exclusive of the lamp. The size of the bulb for vacuum lamps is determined primarily by the amount of light depreciation acceptable during the burning life of the lamp.

Tungsten metal evaporates the same as a liquid if it is raised to a high enough temperature. If there is no counter-pressure exerted on the filament to retard the rate of evaporation—analogous to the difference in boiling point of a liquid at high altitudes and at sea level—the amount of condensation on the walls of the bulb will be proportionately greater before the filament fails. Considered from this angle alone, the total area of the bulb surface must be correspondingly greater for a vacuum lamp than for a gas filled lamp of the same wattage rating.

As this condensed film of tungsten increases in density with continued burning of the lamp, more light and radiated heat is absorbed by the film and the temperature of the bulb wall rises. Chemicals, known as "getters" introduced into vacuum lamps during their manufacture convert some of the evaporated tungsten in such a manner that more light and heat radiation is allowed to get through. In other words, the getter reduces the degree of drop in light output and rise in bulb wall temperature before the filament fails. The temperature rise in vacuum lamps, however, is insignificant compared to the light absorption characteristic. The latter, therefore, becomes the predominating factor in the choice of bulb size for this class of lamps.

Gas filled lamps, on the other hand, operate at much higher bulb temperatures than vacuum lamps. By introducing an inert gas into the lamp,

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Pasadena, California, August 21-24, 1950. Author: Lamp Engineering Department, Westinghouse Electric Corp., Bloomfield, N. J.

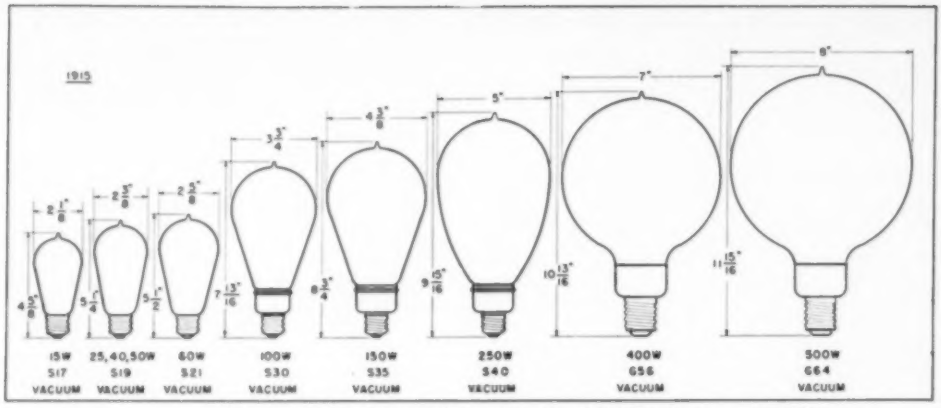

Figure 1. Bulb shapes and sizes for general lighting lamps — Year 1915.

a pressure is applied on the filament and the rate of tungsten evaporation at a given filament temperature is substantially reduced. Conversely, it permits the filament to operate at a higher temperature over a longer period before it fails. The gas, however, has the disadvantage of high heat conduction compared to a near vacuum and the heat thus conducted to the walls of the bulb and base causes them to operate at correspondingly higher temperatures. In addition, convection currents set up in the gas cause some parts of the lamp to operate at higher temperatures than others.

In spite of the extra wattage which must be supplied to the filament to compensate for the "gas loss," the fact that it can operate at a higher temperature during its life more than compensates for this loss in terms of lumens per watt efficiency. This is true, however, only for lamps above a certain ampere current rating with the gas compositions now in common use. The dividing line at present for lamps with single helix wound filaments is close to one quarter ampere current rating which is equivalent to a 30-watt lamps in the 115- to 125-volt range classification.

Not only is the initial efficiency higher in gas filled lamps, but the efficiency after a definite interval of burning—usually measured at seventy per cent of their rated life — bears a closer relationship to the initial efficiency as a result of the repressed filament evaporation.

One of the major phases of engineering and development on gas filled lamps since their inception has been to reduce the extra watts required to compensate for the gas loss. Much has been accomplished by blending in a gas of lower ther-

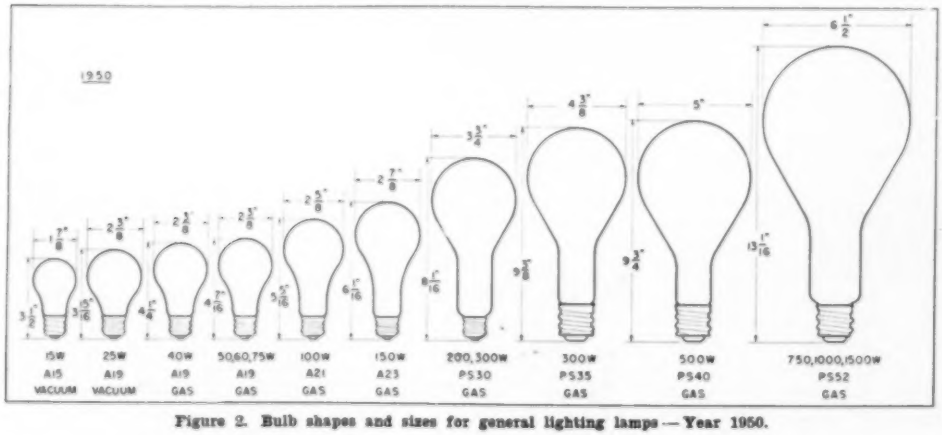

Figure 2. Bulb shapes and sizes for general lighting lamps — Year 1950.

mal conductivity with the nitrogen originally used in general lighting lamps and by reducing the effective surface area of the filament exposed to the cooling action of the gas. The former involved blending in increasing amounts of argon gas as it became economically feasible; the latter involved a change from single helix to double helix (coiled coil) filaments. By reducing gas losses, lamp efficiencies are not only improved but lamp operating temperatures are correspondingly reduced. It is this combination which offers more opportunity for reducing bulb sizes on gas filled lamps than on vacuum lamps. The choice of bulb, therefore, becomes a matter of three primary considerations: (1) permissible drop in lamp efficiency during life ,(2) permissible maximum operating temperature of the bulb and base, and (3) the economics of bulb and lamp manufacture.

Criteria for the permissible drop in lamp efficiency during life is a one way affair for both vacuum and gas filled lamps. It shall be no more than the pattern set by previous commercially acceptable lamps for the service. The maximum permissible operating temperature of the bulb shall be that which will not affect the burning quality of the lamp. This is in the neighborhood of three hundred degrees centigrade for the type of glass now commonly used in general lighting lamp bulbs. The maximum permissible operating temperature of the base, however, is limited by considerations outside of the lamp itself. Of these, the primary consideration is given to the maximum temperature at which the insulation in the socket can operate without deterioration of its insulating properties. It therefore involves both fixtures and lamps.

In order to obtain a standard by which to establish a limit for base temperature, the variable among fixtures in respect to ventilation had to be eliminated. It also had to be related to the most severe condition likely to be encountered. Two "typically hot" fixtures were accordingly selected back in the middle nineteen thirties to serve as standards for the lower wattage lamps commonly used for residential service; one (Fig. 3 designated as 4b) which would not accommodate lamps in bulbs larger than A21, and another (Fig. 4, designated as 4c) which would take A23 and US25 bulb lamps. At that time the highest wattage used for general lighting in these bulbs was 75 in the A21 bulb, 100 in the A23 and 150 in the US25, all single helix (C9) filament shape. Socket temperatures with the highest wattage lamps in their respective fixtures were determined as close to 125 degrees centigrade at 25 degrees ambient. Due to a lack of definite

Figure 3. Test Fixture Type 4b.

Figure 4. Test Fixture Type 4c.

TABLE I.—Socket Temperatures in Test Fixtures 4c and 4b — 100-Watt Lamps in A23 and A21 Bulbs.

LAMP			MAX. OVERALL LENGTH (INCHES)	LIGHT CENTER LENGTH (INCHES)	FILAMENT SHAPE	FIXTURE	SOCKET TEMPERATURE (DEGREES CENTIGRADE)
WATTS	VOLTS	BULB					
100	120	A23 I.F.	6 1/16	4 3/8	C9	4c	118
100	120	A21 I.F.	5 5/16	3 7/8	CC6	4c	130
100	120	A21 I.F.	5 5/16	3 7/8	CC6	4b	140

TABLE II.—Socket Temperatures in Test Fixture 4b — 75-Watt Lamps in A21 and A19 Bulbs Compared with 60-Watt Lamps in A19 Bulbs.

LAMP			MAX. OVERALL LENGTH (INCHES)	LIGHT CENTER LENGTH (INCHES)	FILAMENT SHAPE	FIXTURE	SOCKET TEMPERATURE (DEGREES CENTIGRADE)
WATTS	VOLTS	BULB					
75	120	A21 I.F.	5 5/16	3 7/8	C9	4b	126
75	120	A19 I.F.	4 7/16	3 1/8	CC6	4b	137
60	120	A19 I.F.	4 7/16	3 1/8	CC6	4b	121

knowledge as to the life of fixtures in service and of the time-temperature effects on the socket insulation, this temperature of 125 degrees was adopted as the criteria for maximum temperature on the premise that these lamps had been commercially acceptable over a period of years.

In 1938 the 100-watt lamp was changed to the coiled coil filament shape in an A21 bulb of the same dimensions as the 75-watt single coil lamp. This placed it in the category where it could be used in the 4b type fixture. The socket temperature in this fixture reached 150°C as measured in an ambient temperature controlled room, actually a large insulated refrigeration room, where variables due to drafts and air currents were eliminated. This temperature as well as concurrent checks on the old and new lamp in the 4c fixture are tabulated in Table I.

Since the 100-watt coiled coil filament lamp in the A21 bulb has now had commercial acceptance for over ten years, its socket temperature was used as a base for exploring the possibility of making a coiled coil filament 75-watt lamp in an

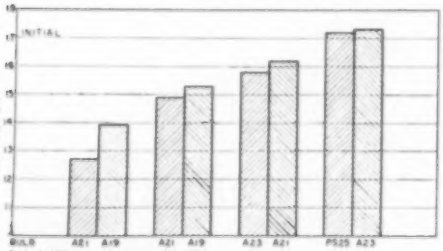
INITIAL
LUMENS PER WATT
BULB A21 A19 A21 A19 A23 A21 PS25 A23
FILA SHAPE C9 CC6 C9 CC6 C9 CC6 C9 CC6
WATTS 60 60 75 75 100 100 150 150

Figure 5. Initial efficiency — comparison of previous and present standard bulb sizes and filament shapes.

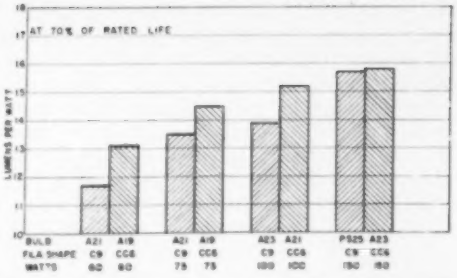
AT 70% OF RATED LIFE
LUMENS PER WATT
BULB A21 A19 A21 A19 A23 A21 PS25 A23
FILA SHAPE C9 CC6 C9 CC6 C9 CC6 C9 CC6
WATTS 60 60 75 75 100 100 150 150

Figure 6. Efficiency at 70 per cent of rated life — comparison of previous and present standard bulb sizes and filament shapes.

A19 bulb of the same dimensions as the already established 60-watt coiled coil filament lamp. If this reduction in bulb size were possible, an increase of about twenty-five per cent in illumination might be realized from fixtures heretofore limited to 60-watt lamps. Tests showed that the socket temperature would be no higher than that which is acceptable for the 100-watt lamp and that the lamp efficiency characteristics would be at least as good as the single coil lamp in the larger bulb. Table II shows the socket temperature values and Figs. 5 and 6 the lamp efficiency comparisons.

Similarly, the 150-watt lamp was explored from the standpoint of possible change from a PS25 bulb single coil filament design to a coiled coil filament in an A23 bulb of the same dimensions as the former 100-watt lamp. This should net a gain of approximately sixty per cent in lumens from fixtures limited to the A23 bulb. Although this design shows three degrees higher socket temperature in the 4c fixture than the 100-watt A21 bulb lamp in the 4b fixture (Table III) this

TABLE III.—Socket Temperatures in Text Fixture 4c — 150-Watt Lamps in PS25 and A23 Bulbs.

LAMP			MAX. OVERALL LENGTH (INCHES)	LIGHT CENTER LENGTH (INCHES)	FILAMENT SHAPE	FIXTURE	SOCKET TEMPERATURE (DEGREES CENTIGRADE)
WATTS	VOLTS	BULB					
150	120	PS25 I.F.	6 15/16	5 1/4	C9	4c	126
150	120	A23 I.F.	6 1/16	4 3/8	CC6	4c	143

TABLE IV.—Socket and Maximum Bulb Temperatures — Bare Lamps. (Keyless Fibre Lined Sockets on Drop Cord. Location as in Fig. 3.)

LAMP			MAX. OVERALL LENGTH (INCHES)	LIGHT CENTER LENGTH (INCHES)	FILAMENT SHAPE	BARE LAMP TEMPERATURE — DEGREES CENTIGRADE					
						SOCKET			BULB (MAX.)		
WATTS	VOLTS	BULB				BASE UP	BASE DOWN	HORIZONTAL	BASE UP	BASE DOWN	HORIZONTAL
60	120	A19 I.F.	4 7/16	3 1/8	CC6	96	83	87	188	210	218
75	120	A19 I.F.	4 7/16	3 1/8	CC6	108	92	97	199	215	223
100	120	A21 I.F.	5 5/16	3 7/8	CC6	108	96	98	138	229	248
100	120	A23 I.F.	6 1/16	4 3/8	CC6	114	91	97	142	231	252

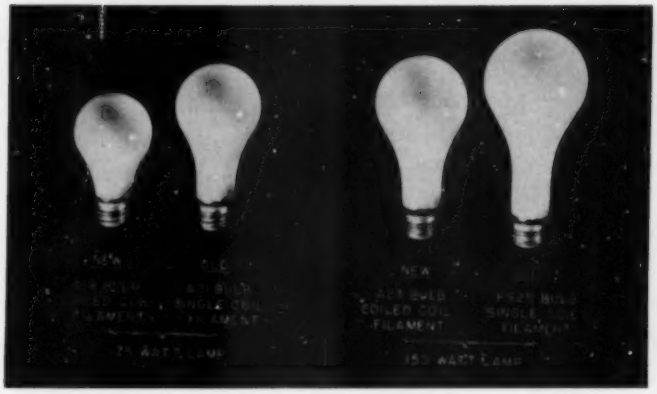

Figure 7. Latest in the series of bulb size reductions.

difference was considered within the degree of significance applicable to the measurement and to its effect on the socket insulation.

The efficiency characteristics of the coiled coil filament in the A23 bulb also complied with the established criteria as noted in Figs. 5 and 6. Table IV lists the socket and maximum bulb temperatures obtained on bare lamps for comparison purposes.

In consequence of the information here presented, the 75-watt lamp in the A19 bulb with a coiled coil filament and the 150-watt lamp in the A23 bulb with a coiled coil filament have been standardized. Fig. 7 illustrates the comparative size of the old and the new.

The gap in the line of high efficiency 50-, 60- and 100-watt lamps with coiled coil filament has thus been closed by conversion of the 75-watt lamp and the line extended to include the 150-watt lamp. These are the lamps in greatest demand for general and residential lighting service.

That which has been accomplished is a step towards the general objective stated at the beginning of this article — the promotion of higher illumination levels by providing lamps of higher wattage that will fit into fixtures originally designed for lower wattage lamps. Whether it can profitably be extended to lamp wattages above or below those already established, is a subject for continued study and development.

DISCUSSION

C. L. Dows*: First, we should like to clarify how 125C was selected as a criterion for maximum socket temperature as the author has suggested. This value was chosen in the year 1925 only after very careful tests in which all the major lamp companies cooperated. These were conducted on many different makes of socket linings under oven temperatures ranging from about 105C to 150C, and even higher on special samples of socket insulations. In addition, service tests were made in fixtures which gave temperatures at the socket from about 125C to 150C. These tests showed quite conclusively that temperatures around 125C were consistent with good socket life. Since the deterioration of the socket lining is a function of both time and temperature, any increase in the socket lining temperature will shorten the effective life of the socket.

Over these many years the lamp industry has itself accepted the responsibility of safeguarding the public against base temperatures that are questionable in their long-term effect on safety and fire hazard. Having in mind this objective, the temperature of 143C for the 150-watt, A-23 lamp in Table III is too far out of line with the criterion which has proved its worth in the past. As the author has stated, this figure is three degrees higher than the 140C figure for the socket temperature of the 100-watt lamp in Fixture 4b as shown in Table I.

We cannot agree that there has been any extensive experience over the ten-year period in actual use of 100-watt A-21 lamps in Fixture 4b or equivalent. True, dimensionally such use is possible, but the brightness of the close-fitting shade with 100-watt lamp is just not tolerable under any ordinary service conditions. The author's rationalization, therefore, proceeds from what seems to be a false premise.

Enclosing units not unlike Test Fixture 4c except that they are both smaller and hotter have been and still are being sold nationally for kitchen and similar use. These show temperatures as much as ten degrees higher than those found in Fixture 4c, that is higher than 150C. The lamp ought, therefore, to be somewhat longer than is the 150-watt lamp in Table III, to avoid future difficulties.

W. E. Anderson*: We wish to express our appreciation to Mr. Dows for his interest and comments, and particularly for his clarification of the basis on which the 1925 criteria for maximum socket temperatures were established.

By the very fact, however, that the 100-watt lamp was actually changed to an A-21 bulb on an industry-wide basis and that no dimensional limitations were offered as to its use in the 4b type fixture, this fact must be faced regardless of whether the brightness of the close-fitting shade might not be tolerable to a certain proportion of consumers. Whether a ten-year period of such use is sufficient to establish commercial acceptability is, of course, a matter of professional opinion.

Allowing for an average service life of 750 hours for each lamp, we feel that there have been sufficient renewals in the same fixture over this period to have brought to light any questions of its effect on socket insulation. This, coupled with the fact that millions of the lamps have gone into service and that the demand has been constantly increasing, further substantiates our belief that a sufficient proportion have gone into these fixtures to establish their acceptability.

Mr. Dows' comments in respect to the 4c fixture are well taken: that fixtures can be and have been built that run hotter than the criteria adopted for socket temperatures. We must, however, draw the line somewhere, and require that fixture manufacturers bear at least part of the burden of providing safe and adequate illumination with the light sources that can be accommodated in their fixtures. We can only assume that they recognize and accept this responsibility.

*General Electric Co., Nela Park, Cleveland, Ohio.

*Author.

Figure 1. BEFORE — "no relief from bright spots."

Figure 2. AFTER — "problem is solved."

Directional Lighting for Dental Clinics

By PAUL W. SEAGERS

IN DECEMBER 1947 the author was given the task of recommending planned illumination for the main clinic of the Indiana University Dental College, located on the Indianapolis campus. This room was approximately 120 feet long and 56 feet wide at its largest dimensions. The ceiling was 21 feet above the clinic floor. (See Fig. 1.) It contained approximately 77 dental units and was lighted with glass diffusing type fixtures. The room had been recently painted. The ceiling reflection factor was about 70 per cent and the wall about 47 per cent. The intensity readings on the instrument trays, on account of artificial lighting, averaged 10 footcandles. There was considerable complaint of eye fatigue, and it is no wonder. Did you ever try to discriminate between natural tooth enamel and porcelain in a person's mouth flooded with 250 footcandles of illumination and then suddenly attempt to find a small stainless steel explorer or a tiny bit of amalgam laying on a clean paper

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Figure 3. View of installation across the room — "readings . . . well within 45 to 60 footcandle range."

Figure 4. View of installation diagonally from rear of room — "members of the dental staff are enthusiastic."

doily in a feeble light of 10 footcandles? That was bad enough, but to make it worse there was no relief from the bright spots produced by the glass globe luminaires, except by looking downward.

Samples of many different luminaires were tried out. In each case, when any reasonable lighting level was obtained on the instrument trays, the patient facing the fixtures had to endure blinding light. Dr. Hine, Dean of the Dental School, suggested that we find the best solution possible even if it took considerable time.

After further experimentation, it was decided that a luminaire must be developed which would (1) maintain an intensity at tray level of 45 to 60 footcandles; (2) distribute the light uniformly throughout the room, including the ceiling; and (3) control the light, so that there would be no bare lamp or excessive brightness within the patient's field of vision as he assumed a reclining position. In theory a high-grade luminaire with baffles along the main axis of the fixture tilted 45 degrees away from the perpendicular should do the job in these respects.

A sample fixture meeting these requirements was installed for test. After several months of checking, we knew we had solved the problem, and luminaires similar to the experimental unit were permanently installed. We installed nine rows of four-tube fixtures four feet below the ceiling. In seven rows we used five eight-foot fixtures and in the two short rows we used three eight-foot and one four-foot fixture.

After two hundred hours of use readings and photographs were taken. The readings fell well within our 45 to 60 footcandle range. Fig. 2 shows the installation diagonally from the front. Fig. 3 is taken across the room and Fig. 4 is taken diagonally from the rear of the room. Although it is difficult to tell much about lighting from photographs, it is thought that these do offer some evidence of uniformity of lighting.

To the patient, the photograph shown as Fig. 5 is the most important. This gives a patient's eye view of the fixture when in a complete reclining position. The normal vertical light was directed past the patient's eyes and all side and reflected light was well within the limit of tolerance. Patients and members of the dental staff are enthusiastic about the results. The point of fatigue for both groups is not only delayed but greatly lessened in intensity. Perhaps general directional lighting similar to this installation can be adapted to dental and medical examination and operation rooms, large display areas and audio-visual education rooms. At least it gives the creative engineer something to think about.

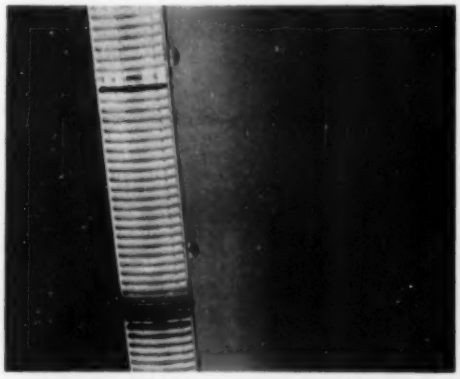


Figure 5. Patient's eye view — "most important."

Application Data For Proper Dimming of Cold Cathode Fluorescent Tubing

By WILLIAM P. CARPENTER

A general opinion exists that fluorescent tubing cannot be dimmed, or that if it can be dimmed, the method, design, and apparatus required are of exceedingly complicated nature. Some difficulty has also been experienced in the past in which attempts to dim non-mercury neon sign tubing have been made. The neon-filled non-mercury sign tubing is generally unsatisfactory for dimming applications and the use of tubing filled with a mercury-argon mixture is recommended. The data given here are based upon the use of such tubing.

TO DIM cold cathode fluorescent lamps or tubing properly, all that is required is a proper coordination of the three essential pieces of apparatus. This apparatus consists of the tubing, the luminous tubing transformer, and the dimmer. A chart is presented in this article which coordinates the three items, and by simply following the recommendations given in the chart, satisfactory dimming down to about 5 or 10 per cent of full light output will result. It should be noted that a high voltage transformer of the luminous tubing type is specified. The single-lamp or two-lamp ballast does not provide satisfactory dimming effects under ordinary conditions.

Lamps

The fluorescent tubing recommended for dimming is of the cold cathode type, and for best results, should be made to high quality standards and should be uniform in electrical characteristics. If all tubes or lamps are of uniform high quality, no difficulty should be experienced in dimming in conformity with the chart. However, the custom tubing may vary from manufacturer to manufacturer because of variations in measuring equipment, gas purity and processing techniques. However, even such custom tubing usually can be satisfactorily dimmed, but often the "cut and try" process must be followed to determine proper transformer loading. In general, custom tubing will dim less readily or flicker at lesser reduction in illumination than standard tubing. This trouble can be alleviated in part by cutting down on the number of feet of tubing per transformer, or increasing the transformer capacity, both in secondary voltage and current. If higher current is used, care must be exercised in order not to burn up the electrodes of the tubing.

Good dimming results can be expected when the standard 93-inch tube made in conformity with the standards of the Fluorescent Lighting Association is used. These tubes should be mounted in approved sockets, wired with proper high voltage cable, and all suggestions and precautions of good lighting practice for this type of equipment should be followed.

Low temperature causes low light output from cold cathode fluorescent tubing, poor starting, and poor dimming characteristics. The data given in this article are for applications at average room temperature of 60°F to 80°F. Dimming can be achieved at lower and higher temperatures, but the accompanying reduction in allowable change in intensity of illumination must be tolerated.

To summarize the items of consideration regarding lamps, the following recommendations should be followed:

A. Procure lamps of reputable manufacture.

B. Use only tubing containing mercury.

C. Do not connect more feet of tubing to transformer than recommended in the chart.

D. For best results, do not use short lengths of lamps or custom tubing of questionable caliber.

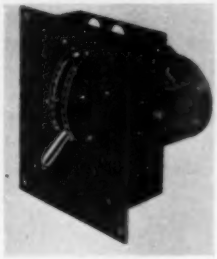
E. Do not run high voltage cable in long runs of close fitting conduit. This will produce a capacitive loading on the transformer.

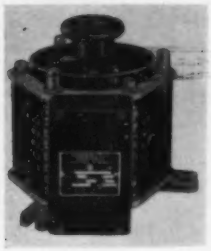
High Voltage Transformers

The ballast type of transformer operating at approximately 750 to 1000 volts is not recommended for dimming. The type of transformer suitable for dimming is the luminous tubing transformer which has a secondary voltage of several thousand, and a short circuit current upwards to 120 ma.

These transformers can be obtained from one of

Author: Chief Engineer, The Superior Electric Co., Bristol, Conn.





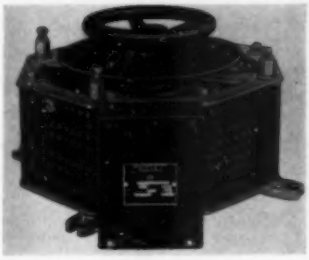


Figure 1. (above left) 1000-watt variable transformer dimmer.

Figure 2. (above center) 2000-watt variable transformer dimmer.

Figure 3. (left) 5000-watt variable transformer dimmer.

Figure 4. (right) Three-section, 15,000-watt total motorized autotransformer dimmer.

many reputable manufacturers and are described as "transformers for series operation of cold cathode fluorescent tubing" or "luminous tube transformers." It is possible to obtain these transformers in the uncorrected power factor type or in the power factor corrected type. The latter is recommended inasmuch as a smaller dimmer is required.

Luminous tubing transformers are also available from at least one manufacturer with a constant voltage feature incorporated within the transformer. This is a very excellent feature when dimming is not required because the transformer produces essentially a constant secondary voltage with changes in line voltage. However, in the case of the dimming method described here, the secondary current is required to vary in response to primary voltage changes produced by the dimmer, and of course, self regulation must not be included. The chart contained within this article lists the volt-amperes required by transformers having the secondary voltage and current characteristics listed. In each case, it is well to check the name plate on the transformer to be sure that the particular design coincides with the data given in the chart.

Regarding the effectiveness of protective devices required by the National Electric Code, to date the writer has not been able to study their performance in dimming circuits.

Dimmers

Dimmers for general use may be classified as the continuously adjustable autotransformer type, the rheostat type, and the saturable core reactor type. For dimming cold cathode tubing, the autotransformer type is most commonly used because of its availability in packaged forms, its high efficiency, simplicity in wiring, and insensitivity to load variations. Only the variable autotransformer type is discussed in this paper.

In order properly to supply the high voltage transformer for the cold cathode fluorescent tubing, the dimmer should have sufficient volt-ampere capacity to feed the transformer, or transformers, connected to it. One manufacturer of autotransformer dimmers offers them in three basic sizes: 1000va, 2000va, and 5000va. Dimmers of larger size are obtained by combining more than one dimmer of the same size on the same operating shaft. For example, were it required to dim a 4000va load, this load could be handled by four 1000-watt dimmers with load properly split, two 2000-watt dimmers with load properly split, or one 5000-watt dimmer. If the load were 12,000 volt-amperes, it could be handled by twelve 1000-watt dimmers six 2000-watt dimmers or one 3-section 15,000-watt dimmer. It can be seen that a great

many combinations of dimmers can be used to obtain flexibility in control.

Fig. 1 shows a photograph of a 1000 volt-ampere autotransformer dimmer which is suitable for many relatively small installations. The chart indicates that this dimmer is suitable for handling a transformer loaded with 70 feet of 25 mm tubing.

Fig. 2 shows a 2000 volt-ampere dimmer which will handle twice as many feet, 140 feet of tubing, while Fig. 3 shows a 5000 volt-ampere dimmer which will handle 350 feet of tubing. The exact footages which the dimmer is to handle are dependent upon how the circuits are broken up.

For good dimming when the circuits are broken

LOADING CHART FOR COLD CATHODE FLUORESCENT TUBING ON DIMMING CIRCUITS.

TRANSFORMER				AUTOTRANSFORMER DIMMER		FEET OF TUBING PER TRANSFORMER			
				VA Capacity for:		White or Colored Tubing Containing Mercury			
Voltage	MA	VA Pf corr'd	VA Pf uncorr'd	Pf corr'd Transformer	Uncorr'd Transformer	25 mm	20 mm	15 mm	12 mm
5000	30	80	150	1000	1000	25	20	16	14
	60	165	300	1000	1000	26	21	18	15
	90	245	450	1000	1000	27	23	20	17
	120	330	600	1000	1000	29	25	22	19
6000	30	100	180	1000	1000	30	24	20	17
	60	200	360	1000	1000	31	26	22	19
	90	300	540	1000	1000	33	28	24	21
	120	400	720	1000	1000	35	30	26	23
7500	30	125	225	1000	1000	38	30	24	21
	60	250	450	1000	1000	39	32	27	23
	90	375	675	1000	1000	41	34	30	26
	120	500	900	1000	1000	44	37	33	28
9000	30	150	250	1000	1000	45	36	29	25
	60	300	500	1000	1000	47	38	32	28
	90	450	750	1000	1000	49	41	35	31
	120	600	1000	1000	2000	53	45	39	34
12000	30	200	360	1000	1000	60	48	39	33
	60	400	720	1000	1000	62	51	43	37
	90	600	1080	1000	2000	65	55	47	41
	120	800	1440	1000	2000	70	60	52	45
15000	60	500	900	1000	1000	80	69	59	56
Recommended Gas Pressure:						6 mm	7 mm	10 mm	13 mm

GAS: Chart based upon B10 gas; 1050 gas or equivalent, plus mercury.

TUBING: Values given are for carefully made high quality tubing.

Lengths: The above chart is based upon the average number of electrodes that would be used for the footage shown. If the number of pairs of electrodes exceeds 10% of the footage, allow two feet for each additional pair of electrodes.

TRANSFORMERS: Use high voltage series luminous tube transformers of reputable manufacture. The power factor corrected design is preferred. Low voltage ballast transformers and voltage stabilizing types of transformers are not suitable for dimming. Do not connect more feet of tubing to a transformer than recommended in chart.

DIMMERS: Some basic ratings for single frame Autotransformer Dimmers are as follows:

Type	Input Voltage	Maximum Output Amperes	Maximum Output VA
1000	120	8.3	1000
2000	120	16.7	2000
5000	120	41.6	5000

These dimmers are available with knob and dial, handle and drum, and motor operated for push button or positioning type of control. The operating form of the dimmer is usually identified by prefix and suffix letter to the basic types.

LARGE INSTALLATIONS: If the installation requires a number of feet of tubing which is too large to be handled by one transformer, the circuits must be broken up into a number of shorter length circuits of *equal* length and suitable transformer selected for the new lengths. Alternatively, proper transformer size must be carefully selected for tube circuits of varying lengths.

The supply to these transformers can then be obtained from a single autotransformer dimmer of the proper volt-ampere rating or from more than one autotransformer dimmer.

As an example, assume it were desired to dim a total of 800 feet of 25 mm white tubing as used for lighting purposes. The chart above shows that 70 feet can be handled by one 120 ma, 12000-volt transformer. Hence, to handle 800 feet, a total of 12 circuits must be used, each requiring one 12000-volt, 120 ma transformer. The power requirement of each transformer is 800 VA as shown on the chart so the total power requirement will be 800 × 12, or 9600 VA. To handle this load, a dimmer such as type D5000-2E (two 5000 VA dimmers on a common shaft) would be recommended. Of course, if more controls were desired, a group of smaller dimmers could be used, such as 12 dimmers, Type D1000.

CAUTION: The data given in the chart above is applicable to installations in which good practice has been employed. Difficulty is sometimes experienced, especially in decorative lighting due to tubing quality, many short lengths of tubing, and capacitive loading on transformers due to running high voltage leads in conduit, etc.

up because it is necessary to use more than one luminous tubing transformer, it must be remembered that the luminous tubing transformers which are employed must be of the same design and have precisely the same rating. Also, in the case of the use of more than one luminous tubing transformer, the transformer tube loading must be exactly the same for each to get uniform reduction in illumination for all the circuits concerned. In other words, if 325 feet of 25 mm tubing were to be dimmed and five circuits were employed, it would be desirable to use 65 feet of tubing on each of the five circuits for best results. If four circuits were loaded to 70 feet and the fifth circuit (using a transformer of equal size) loaded to 45 feet, and the dimmer were adjusted for dimming, it would be observed that the illumination in the 70-foot circuits would decrease most rapidly, and they would reach a point of flickering before the tubing in the 45-foot circuit began to flicker. Thus, either equal footage should be loaded on each transformer of the same rating or proper reduction in transformer size should be made where tubing loads are smaller. In the example given here, there are two solutions: (1) Use five 12,000-volt transformers, each loaded with 65 feet of tubing or, (2) use four 12,000-volt transformers each loaded with 70 feet of tubing and one 7,500-volt transformer loaded with 45 feet of tubing. In any event, balanced tube loading on each transformer is a "must" if uniform dimming is to be achieved on each circuit.

The table shows the new dimming chart recommended for fluorescent tubing, and contains condensed instructions for its use.

Colored tubing containing mercury has dimming characteristics identical to those of white tubing of the same diameter and operated at the same current. For decorative lighting, it is recommended that each color be controlled by a separate dimmer, sometimes called the color dimmer, or color master, in theatre lighting. When the particular colors of tubes are grouped with color dimmers, then color mixing can be achieved by separate operation of each dimmer to produce pleasing shades of color. This is accomplished by properly adding the various proportions of the basic colors.

Summary

No particular difficulties should be experienced in dimming cold cathode fluorescent lighting if the steps outlined above are carefully followed. The chart, together with the explanations, will produce an integrated design in which the lamps, luminous tubing transformers, and dimmers have been selected for overall performance. The greatest difficulties which have been experienced in attempts to dim cold cathode fluorescent lamps have resulted from using too many feet of tubing on a particular size transformer, in using tubing, particularly decorative, of non-standard manufacture, and in using neon-filled (non-mercury) colors. Recognition of the causes of these difficulties and evaluation of their effects will lead to the specification of proper dimmers, lamps and transformers. The architect, designer, or contractor should approach the problem of dimming cold cathode fluorescent lamps without hesitancy in specification, procurement, and installation.

References

Signs of the Times, September 1948 and October 1948. Article by William P. Carpenter.

Business Directory of I.E.S. Membership

An accurate up-to-date business directory of the entire membership of the Illuminating Engineering Society has been compiled under the direction of the Publications Committee, to be available only to members of the Society. Copies of the directory, 6 x 9 inches in size, may be obtained from I.E.S. headquarters at $2.00 for single copies, or $1.75 each for quantities of ten or more.

Orders should be addressed to the Illuminating Engineering Society, Publications Office, 1860 Broadway, New York 23, N. Y.

An Illumination Recorder

By A. H. TAYLOR and W. G. PRACEJUS

New technique and apparatus has applications in street, sports, automotive, theater lighting and other fields where a continuous record of illumination levels is desired.

IN OCTOBER 1944 the Committee on Street and Highway Lighting of the Illuminating Engineering Society submitted to the Council a list of suggested topics for research. One of these was as follows: "A recording instrument, to be mounted on an automobile, to measure horizontal (and preferably also vertical) street illumination." The illumination recorder which is described here will meet these requirements. Obviously, an instrument with the sensitivity and dependability (Fig. 1) required to measure the low intensities of illumination found in street and highway lighting will have many applications outside this particular lighting field.

Up until a few years ago all street lighting measurements were made by visual methods, and experimental errors were rather large, due to many uncontrollable factors. The introduction of physical meters (light cells, etc.) for low illumination measurements probably increased their accuracy, but they were still laborious and somewhat hazardous.

When making a street lighting survey by visual photometry or the low-range light meter method, it is usually necessary to select the lamp span or spans (distance between units) to be measured and then to establish positions for point-by-point measurements. As will be shown later (Fig. 1) individual spans vary appreciably due to differences in lamps and refracting and reflecting media; hence, the span selected for measurement may not be typical. Also, actual illumination values at equally spaced measurement points do not necessarily fall on a smooth curve, as might be assumed. The selection of the span to be measured is usually done by daylight so that appropriate pavement markings can be made. Thus, two trips to the test street are often necessary.

The new apparatus gives a *continuous* plot of the street illumination for as many lamp spans as may be necessary to establish a good average. Marking of test positions on the street is unnecessary, hence the visit to the test area for surveying is eliminated. There are other advantages to this new technique and apparatus.

Authors: General Electric Co., Nela Park, Cleveland, Ohio.

Color and Cosine-Corrected Light Cell

Street lighting authorities prefer a cosine-corrected receiver for measuring street illumination. Such a meter should also have a spectral response approximately the same as that of the average eye,

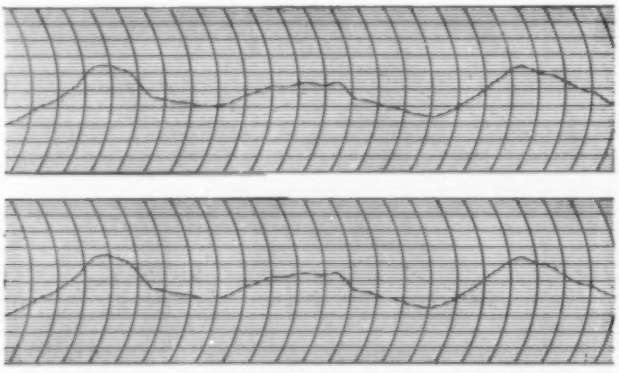


Figure 1. Three lamp spans measured by the Illumination Recorder. Two runs made over the same section of the road to show sensitivity (1 ft-c full scale), and reproducibility.

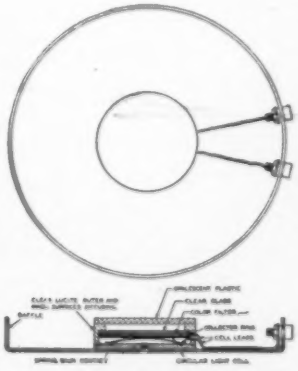


Figure 2. A cross-section view of the color and cosine corrected circular cell.

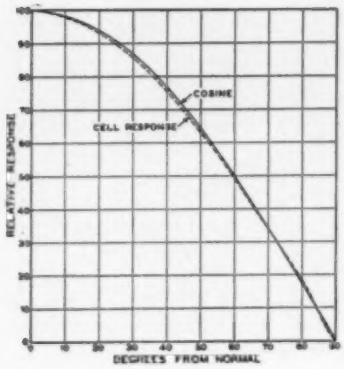


Figure 3. (left) Comparison of the correction achieved for cell with the theoretical response desired.

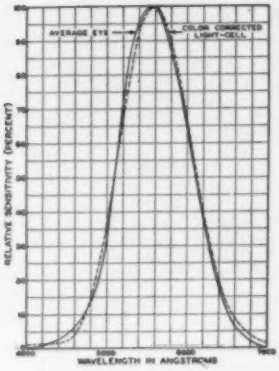


Figure 4. (right) Comparison of the color correction achieved for the cell with the spectral response of the average eye.

so that all illuminants are properly evaluated regardless of their color.

Fig. 2 is a cross-sectional view of a circular photovoltaic cell and housing designed to give cosine correction, and Fig. 3 shows the degree of correction achieved. The incorporation of a suitable color filter results in the color correction shown in Fig. 4. The results indicate excellent cosine and color correction. The latter is very important when mercury sources are used; the correction obtained gives a high order of accuracy, much higher than could possibly be achieved by present visual methods. The announcement of a concurrent development indicates that similar, if not identical, cells are in use at the University of Michigan.*

Amplifier

At illumination levels such as are encountered on the streets the current output of the photovoltaic light cell is too low to operate a graphic recorder without amplification. A great deal of our research has gone into the development of suitable amplifiers. In the measurement of street illumination a linear response appears desirable so that illumination values could be read directly from the graphic recorder chart. In another important application a response approximately logarithmic in character was needed in order for the apparatus to measure very low illumination values accurately and yet have an appreciable illumination range. The amplifier should be stable and free from drift, but it should be possible to check the zero reading at any time without covering the light cell or cells. Also, the sensitivity should be easily adjustable to cover any desired range.

The above objectives have been achieved in two types of amplifier circuits, each employing two stages of push-pull amplification. In one of these, linear response has been obtained with full-scale readings (one milliampere) ranging from 1 to 100 footcandles using the corrected light cell described above. The range could probably be increased without loss of linear response. The other amplifier, with approximate logarithmic response, gives a full scale reading for an illumination of about 0.1 footcandle and could be made more sensitive if desired.

Recorder and Accessories

The amplifier, dry batteries, and recorder are incorporated in the carrying case shown in Fig. 5.

Figure 5. The amplifier, recorder and drive mechanism mounted in a carrying case.

*"The Development of Prismatic Glass Block and the Daylighting Laboratory," R. A. Boyd, Engineering Research Bulletin No. 32, February 1951, Engineering Research Institute, University of Michigan, Ann Arbor, Mich.

Tube heaters are operated on an auxiliary 6-volt storage battery. In operation the carrying case and storage battery are placed on the rear seat and floor of the automobile, respectively. The recorder tape is driven by a flexible cable attached to the speedometer drive, with gear reduction such that the tape speed is directly proportional to car speed. The recorder can, for example, be so geared that one linear division on the chart corresponds to a linear movement of the car of 20, 40, 80, 160 or 320 feet. Indexing pens can be added to give an indication of the position of the starting point, end of run, and unusual conditions encountered during a run. This greatly facilitates interpretation of the data.

Supporting Light Cells for Measurements

In measuring street illumination it is preferable to have the light cell move along the street in a horizontal position, as close to the pavement as possible. This can be accomplished by mounting it on a low cart trailing behind the car at such a distance that the car does not shade it from street lamps which are near enough to make appreciable contributions to the illumination. Fig. 6 shows such a trailer carried 30 feet behind a station wagon, the cell being about 6 inches above the street surface. This arrangement has been successfully used in several tests but usually requires police protection on streets with more than very light traffic.

Another method of cell exposure involves mounting two cells, one on each side of the car, as in Fig. 7. These are connected to the amplifier so that their responses are additive. The sum represents the *total* illumination at some position between them. Street tests have shown that the two methods give substantially the same results, but the latter method (Fig. 7) is much more convenient and flexible for use in traffic. With this arrangement it is possible to use both cells simultaneously, as indicated above, or either cell alone. When using a single cell, with lamps on both sides of the street, it would be necessary to traverse the street twice and add the values. For example, if it is desired to measure the illumination along a line ten feet from the curb, the car would traverse the street once with the left-side cell and once with the right-side cell at this distance from the curb, in each case the other cell being covered or disconnected. The results could then be added to give total illumination. The two-cell method may not be applicable to measurements at distances from the curb less than the overhang of the street lamps, due to shading by the car. Vertical illumination at any desired height above the pavement can be measured by mounting a cell vertically on the back, front or side of the car.

In practical tests on the street it has been found that highly reproducible results can be obtained with this apparatus at car speeds of ten to twenty miles per hour. Fig. 1 indicates the reproducibility of results in successive runs over the same section of street.

By use of an electrical clutch it is possible to engage or disengage the recorder whenever desired.

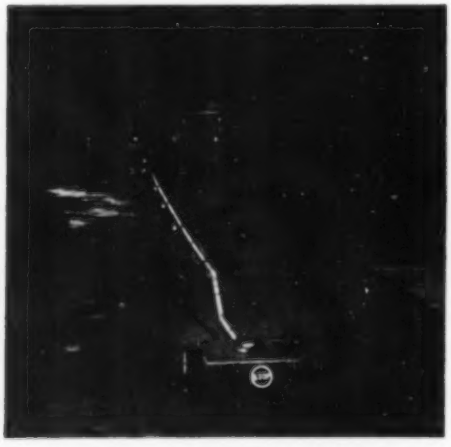


Figure 6. Cell mounted on a trailer 30 feet long and carried 6 inches above the pavement.

Calibration

Since the sensitivity of a photovoltaic cell is affected by ambient temperature, it is necessary to have some method of calibration "on the job." For this purpose the calibrator shown in the photograph of Fig. 8 was developed. A small lamp is enclosed in a light-tight housing which is placed over the light cell. It interposes a diffusing plastic disk between the lamp and the light cell, the area of luminous plastic being adjusted to give the desired illumination on the cell.

When the voltage and current of a miniature lamp are varied the light output varies much faster than either of these. At the electrical operating conditions of the lamp used in the calibrator, a one per cent change in voltage produces a change of 3.8 per cent in light output; a one per cent change in current changes the light output 8 per cent. Consequently, neither voltage nor current is a sufficiently sensitive indicator of the light output

Figure 7. Alternative cell mount placed on the rear bumper of the car and carrying the cells 6 inches above the pavement.

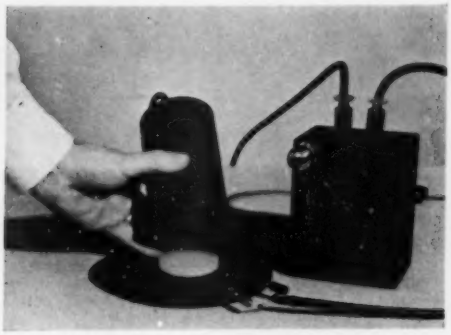


Figure 8. The calibrator used with the circular cell for field calibration. The calibrator was developed for this purpose.

of the standard lamp. In the calibrator two lamps of the same type are placed in diagonally opposite arms of a Wheatstone bridge, with fixed resistors in the other arms. Any unbalance of the bridge is indicated on a panel type 0 to 150 microammeter. With this arrangement the illumination on the light cell is reproducible to an accuracy of greater than 99 per cent after the lamps have been been turned on for about 10 minutes.

Advantages of the Illumination Recorder

With this apparatus it will be possible to record graphically the illumination on several miles of streets in one night. No prior mapping of test stations is necessary. As contrasted with measurements by present methods, the results are continuous rather than point-by-point and are much more reliable. Actual street tests show that there is usually no single representative span (see Fig. 1). The new technique permits one to readily determine maximum, minimum and average illumination values. Vertical as well as horizontal illumination can be measured. It is also possible to study the effect of other factors such as shading by tree branches, non-uniformity of lamp spacing, extraneous light from store fronts and filling stations.

Future developments in street lighting techniques may indicates a need for cells with other than a "cosine" response. The "cosine" response gives little weighting to the energy striking the cell from the grazing angles of incidence. Since the visibility of objects on the pavement appears to be more a function of the grazing or high angle specularly reflected light than the vertical illumination, the authors have considered cell correction to meet this need.

The measurement of horizontal and vertical footcandles fulfills the needs of today's street lighting practice. An instrument to make and record these measurements has not been available. The authors feel that the use of the illumination recorder will develop a desire to consider pavement brightness in the same way and have considered the necessary changes in the instrument to achieve the required amplification.

The availability of a recording instrument such as this has led engineers in other lighting fields to suggest many applications. The limited number of illumination recorders which have been constructed are in use in three fields at the present time. One of these is the street lighting application which has been described. A second is automotive headlighting research, where an uncorrected cell is mounted near the eye of the driver of an automobile. An indexing pen on the recorder indicates the position on the tape at which the driver decides the glare from an opposing automobile's headlights is objectionable. Another application is the measuring of average brightnesses of movie screens and may be extended to include television programs on home receivers.

The illumination on vertical, horizontal and intermediate planes of sports fields is readily measurable with the illumination recorder.

As a result of the development of this new lighting tool, it should be possible to obtain measurements of illumination levels under conditions which in the past have been difficult and sometimes impossible. This should result in more complete information for the design of lighting installations providing quick, accurate, safe and comfortable seeing.

Lighting a Large Office

LIGHTING OBJECTIVE: To provide the level of illumination suitable for the operation of office machines.

Installation at First National Bank, Chicago, Illinois.

General Information: Surface characteristics of this 11-foot high office are as follows:

desks	very dark*	5% RF
floor	gray mottled	30% RF
ceiling	white acoustical tile	80% RF
walls	green	40% RF

Installation: Continuous rows of low brightness, anodized aluminum troffers (Curtis Lighting, Inc. catalogue #1762-C) spaced on 3-foot centers provide a maintained illumination level of 70 footcandles on a plane 30 inches above the floor. Each unit contains one 40-watt T-12 60-inch 4500K low brightness lamp. Power consumed is 3.6 watts per square foot.

Brightnesses are indicated below:

desks	3 ft-L
floor	12-19 ft-L
walls	9 ft-L
ceiling between troffers	4 ft-L
troffers	425 ft-L

Lighting data submitted by C. K. Lambka, Electric Supply Company, Chicago as an illustration of good lighting practice and to aid in the design of similar installations.

*Note: The dark desks do not meet the specifications of the *I.E.S. Recommended Practice of Office Lighting*. Although this installation is a good example of low brightness luminous conditions, lighter furniture would improve the visual environment considerably.

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Author's Rebuttal to Discussion of Paper "Uniformity of Illumination in Highway Lighting"*

D. M. FINCH**: It is encouraging to note Mr. Reid's concurrence on the specific purpose of the paper, namely, the desirability of more uniform pavement brightness, and that the present I.E.S. recommended practice of a permissible ratio of 4 between average and minimum horizontal illumination may be found to be too high for arterial streets under some conditions.

The establishment of a more uniform pavement brightness distribution will provide the motorist with the degree of visibility that he expects to find on modern expressways.

Mr. Reid has incorrectly assumed that the minimum limits suggested in the paper be adopted as a performance specification. This is not the case any more than the present I.E.S. recommendation that the minimum shall not be less than ⅓ the average illumination, is a performance specification.

We are in full agreement with Mr. Reid in that such a performance specification would not be desirable. This has been clearly shown by recent British experience. It is important to note, however, that British practice retains a recommendation for minimum levels of luminance of .07-0.1 f.l. on the roadway. We feel that a minimum value should be established at some appropriate lighting level.

It is interesting to note in Mr. Wyatt's remarks that he considers it desirable to secure a thorough evaluation of a proposed lighting installation, and that good visibility at night is best obtained by adequate pavement brightness, little glare and good uniformity.

We quite agree that any system of lighting should be a balance of economic, quality and aesthetic values, and we would add visibility. It is specifically the matters of economics, quality and visibility with which this paper is primarily concerned. From the results of work done in connection with this paper it is quite evident that a reduction can be made in costs, with an increase in visibility, by a properly designed lighting system in which the factors of illumination levels are balanced against uniformity of pavement brightness.

It is generally recognized that lighting installation costs can be represented by a certain lumens per dollar value. The problem is then to provide the required degree of visibility with the least number of lumens. Thus, Mr. Wyatt's statement is definitely not true, that a ratio of maximum to minimum illumination of 4 to 1 would increase the costs for the improved visibility received in return.

There is evidence to indicate that the added costs of increasing the number of standards required can be more than offset by a decrease in lumens required to provide superior visibility conditions.

Mr. Wyatt's discussion concerning the figures presented in the paper indicate that although he understands that the original data of the study was obtained from isolux diagrams for the luminaires as furnished by the manufacturers, he is concerned about the remainder of the study procedure.

In each case the independent variable is lamp size in lumens, and the dependent variable the spacing in feet.

These lamp values are used with the coefficient of utilization (0.417 for type IV, 0.456 for Type III, with 102′ roadway), highway width, and average illumination, to give the required spacing meeting these conditions.

The presence of a single curve in the upper right quadrant of the performance curves merely confirms Mr. Wyatt's earlier remark that a change in lamp size does not vary the maximum-minimum ratio.

Let it be emphasized that there are not assumptions made in the development of these luminaire performance curves. All data are taken from manufacturers' isolux curves and utilization coefficients.

Mr. Wyatt has attempted to determine the coefficients of utilization and compute the lumens required by using numerical values that were used in the paper's discussion. It should be recognized that the discussion mentioned only rounded values. To clear up Mr. Wyatt's miscalculations on this matter the following relations as used in the study are listed:

Roadway 102′	For 2000-lumen lamp
Luminaires Type IV	$\text{Spacing} = \dfrac{.417 \times 2000}{102 \times .6} = 13.7'$
U.C. = .417	For 20,000-lumen lamp
Ave. Ill. = .6	$\text{Spacing} = \dfrac{.417 \times 20{,}000}{102 \times .6} = 137'$
Roadway 102′	For 2000-lumen lamp
Luminaires Type III	$\text{Spacing} = \dfrac{.456 \times 2000}{102 \times .6} = 14.9'$
U.C. = .456	For 20,000-lumen lamp
Ave. Ill. = .6	$\text{Spacing} = \dfrac{.456 \times 20{,}000}{102 \times .6} = 149'$

From these calculations it is evident that the spacing varies directly as the lamp size, and that there are no discrepancies.

Mr. Wyatt requested an explanation as to why the performance curve for the Type III luminaire, as shown in Fig. 2 showed a change in maximum to minimum ratio from 10 to 20 for a change in spacing of from 71 to 75 respectively. An inspection of the isolux curves, show in in Fig. 15 for the Type III luminaire, will readily explain this. It will be noted that for spacings in excess of 60′ for a roadway width of 102′ there is a very rapid decrease in horizontal footcandles. The variation in the maximum to minimum ratio caused by this rapid decrease is indicated by the steeply rising curve.

For purposes of useful illumination, any values less than .001 ft-c. were not considered effective and were dropped. In answer to Mr. Wyatt's question concerning the validity of the maximum to minimum ratio of infinity shown on Fig. 2, we will admit that to be mathematically correct this value should have been 2.5/.001 or 2500 instead of infinity as shown.

Mr. Wyatt's notation that if a line is projected straight up from the point of intersection of the I.E.S. recommended minimum and the plotted minimum illumination curve in Fig. 2 will show a ratio of 6 to 1 is correct, but this value only applies for a lamp size of 8,000 lumens. This fact was discussed in the detail in the paper. It is quite obvious

*Paper was published in April issue of ILLUMINATING ENGINEERING (pp. 199-211) with discussions by Kirk M. Reid, F. D. Wyatt and C. H. Rex.

**Author: College of Engineering, University of California.

that for a 20,000-lumen lamp and the I.E.S. recommended minimum of .15 ft-c. for a 0.6 average value, the ratio will be 25/.15 or 16.6, or as stated in the paper, 17 to 1.

In view of the fact that the Standard Practice recommends average horizontal footcandle values from 0.3 to 1.2 it appears to the authors of this paper that the recommended minimum of ¼ the average can vary from 0.08 to 0.3 h.f.c. which is far from being definite and appropriate, since it covers quite a range of values, and permits a maximum to minimum ratio of from 1.5:1 to 17:1.

It is encouraging to note that Mr. Wyatt concurs in that the establishment of a maximum to minimum ratio would be of merit, but we question the validity of his statement that to attain this would be difficult or expensive. If he will refer to Figs. 9 and 11 he will see how ratio values as low as 1.2 to 1 have been secured with quite normal installations.

Mr. Wyatt considers that he can handle one isolux chart but considers two of them rather formidable. In the use of the isolux curves for the study in this paper we found the use of two or more isolux curves relatively simple to handle and had no difficulty in determining the points of maximum and minimum intensity, from which we were able to secure the illumination ratios.

The matter of the number of performance curves required is, of course, important and the actual number will depend upon the number of mounting heights and street widths used.

For the purpose of this study the three sets of performance curves shown are sufficient to cover 90% of the cases since mounting heights in this area have been standardized at 30'. It is significant to note that small changes in street widths are not critical and a reliable answer for other values can be secured by interpolation.

We wish to emphasize again that *all* the curves presented in this paper are based on luminaire performance data furnished by the manufacturers of the luminaires studied.

The recommendations given by Tables II and III are based on many field observations and engineering judgment in an attempt to provide the type of lighting that is considered adequate for modern expressway traffic.

The emphasis that Mr. Rex has placed upon the huge expenditures for automotive transportation serves to remind the highway lighting design engineer that the proportion of this amount that is expended for highway lighting facilities should provide the motorist with an order of night visibility that is commensurate with the modern expressway highways that are being provided for the motorist.

In response to Mr. Rex's request for all available proof data substantiating an increase in illumination uniformity, we wish to remark that an engineering performance standard, such as I.E.S. recommended average illumination procedure, that permits a variation in illumination of as much as from 1.5:1 to 16.6:1, depending upon the type of luminaire selected, should be re-examined to uncover its shortcomings.

We wish to acknowledge Mr. Rex's data sheets for luminaires manufactured in 1918, but beg to advise that we no longer consider luminaires of this vintage suitable for modern expressways. We would be pleased to see the information as represented in this paper, made available for 1951 models.

Author's Rebuttal to Discussion "Daylight in Classrooms—Multilateral Lighting"*

R. L. Biesele, Jr.**: Comments of the discussors indicate that certain points in my paper need clarification. In the first place, no attempt has been made in the paper to "approve" or "disapprove" any of the arrangements tested. The data has been presented as it was obtained, and the recommendations in the American Standard Practice for School Lighting covering brightness ratios and illumination in classrooms were included for comparison, with the thought that the effectiveness of the various systems studied could be evaluated by the architect and the engineer as a basis for their own design work. Most of the arrangements reported in the tables either met fully or very closely approached these recommendations from the Standard Practice. There are many ways to daylight a classroom, but actual data on such methods has been almost totally lacking in the past. It has been the purpose of this paper and my previous one to present such data from our test program.

Concerning the questions by both Dr. Vincent and Mr. Sampson, in Figures 8, 9 and 10 the line of sight is shown directed horizontally and straight forward for the particular seat in question. The center of the line of sight for this viewpoint has been taken as the task in the data given in the tables. There was some question whether this point should be selected or whether the student should be assumed to rotate in his seat and look at the front chalkboard. Since tackboards and display materials frequently are placed at this inside point on the front wall, and since this was the point of lowest brightness as well as the center of the line of sight for a student facing straight forward, it was felt that we should use this as the task in the heads up view. This means actually that the brightness ratios of window to task (0-90° maximum-to-task ratio of Table III) have their greatest value as we have presented the data.

In addition to this confusion with regard to the visual task in the heads up view, which explains some of the apparent discrepancies pointed out by Mr. Sampson, there is one further difficulty. The data shown in Figures 6 and 9 are for Test BL-17, while Mr. Sampson has taken from the table for his comparison the ratios given for Test BL-20. Mr. Sampson's comment concerning complete freedom of seating arrangement is well taken, but if we are to accept such complete freedom, we will for the present have to do so at a sacrifice in the brightness patterns provided for the pupils.

Discussion of the chalkboard reflection factors would be entirely too lengthy to go into here. The reflection factor employed in our test is the same as that for the walls

*Paper was published in April issue of Illuminating Engineering (pp. 212-220) with discussions by H. B. Vincent, W. C. Randall, R. W. McKinley, and Foster K. Sampson.
**Author.

(60%) which presupposes a light board for use with dark chalk. As indicated in the paper, reflection factors of room surfaces, as well as seating arrangements, are important factors in the visual environment.

In reply to Mr. McKinley, I would only point out that the brightnesses shown for the glass block panels on the sun exposure for the tests he refers to are 330, 1240, and 840 footlamberts, respectively, while the values shown for a properly adjusted venetian blind on the sun exposure of my Figure 9 are 260, 203, and 267 footlamberts.

Mr. Randall has brought up two points of considerable interest. Ground reflection has turned out to be quite important in our data. A two-year average shows ground reflection contributing 36% of the light incident on the windows for overcast skies, and 37% for clear skies on non-sun exposures. Since our data has been adjusted to a base of 500 footcandles incident on the vertical windows, with the reading of actual incident illumination including the light from both sky and ground, our illumination and brightness values are actually low by roughly ⅓ as compared with what we would have obtained had we based our data on the incident light from the sky alone.

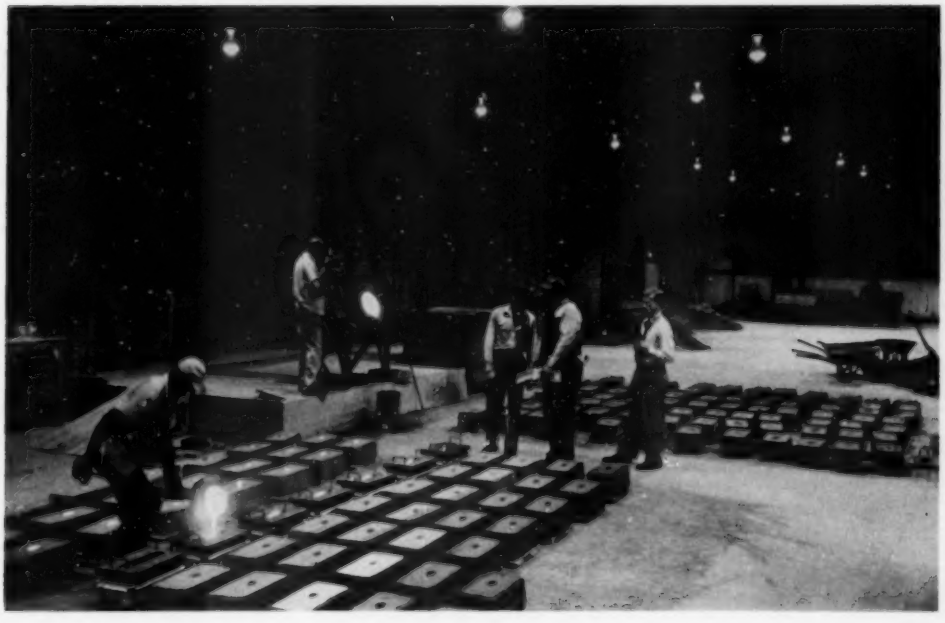
Mr. Randall's second question concerning the desirability of holding window brightness to some maximum such as 500 footlamberts gets right at the heart of the entire daylighting problem. The available daylight is always highly variable. Our work of the past several years has forced us reluctantly to the conclusion that daylight controls must be adjustable to accommodate these variations. To set an arbitrary limit of maximum window brightness, which is highly desirable, would require not only that the controls be adjustable but that this adjustment be performed automatically. Daylighting practice is waiting for a fool-proof and economical solution to just this problem.

Industrial Reflector Lamp in Difficult-Maintenance Areas

Shown below are 500-watt R-52 industrial reflector lamps installed in a foundry of the Southern Shuttles Division of Steel Heddle Mfg. Co., Greenville, S. C. Maintenance factor of an installation of this kind is of the order of 80 per cent even when the only attention given to the system is replacing the lamps when they fail. Mounting height is 16 feet and spacing is 16 feet by 16 feet except over major working areas where an additional unit is mounted over each square. Average illumination is 40 footcandles.

The lamps, which measure 6½ inches across the face and 11¾ inches in length, have a special contour designed to distribute light downward and a cutoff to give reasonably comfortable brightness down to 35 degrees below the horizontal. The base is of the mogul screw, mechanical type and the lamps should be burned base-up or within 25 degrees of that position.

The bulbs should not be touched by accessory equipment and should be protected from falling water. For uniform illumination, spacing between units should not be greater in distance than the mounting height. (Photo courtesy of General Electric Co,. Nela Park, Cleveland, Ohio.)



Lighting of Control Rooms

Prepared by Subcommittee on Control Room Lighting of the Committee on Lighting of Central Station Properties*

Foreword

LIGHTING OF CENTRAL STATION PROPERTIES

The lighting of Central Station Properties, and especially generating and substation areas, presents many peculiar seeing problems and conditions which are not typical of work areas in general. Accordingly, in 1948 the I.E.S. Council established a Committee on the Lighting of Central Station Properties, to study conditions and prepare general recommended procedures to serve as a guide for the industry. The first of these reports, the Lighting of Control Rooms, is now complete. It is based in part upon a preliminary report drawn up in 1948 by Wesley S. Mowry from studies of instrument panel board lighting conducted for the I.E.S. Lighting Study Projects in Industry Committee by a group of volunteers. The first of these reports, the Lighting of Control Rooms, is now complete.

Other reports which are scheduled for the immediate future are:

Lighting of High Bay Areas
Lighting of Load Dispatch Rooms and Telephone Switchboard Rooms
Lighting of Outdoor Areas.

It is planned that all of these reports shall be in accordance with latest knowledge and practices. However, future progress in the art and science of illumination will doubtless make a revision of these recommendations desirable.

SUBCOMMITTEE ON CONTROL ROOM LIGHTING

W. B. Morton, *Chairman*

R. M. Graves	L. G. Parks
W. S. Mowry	D. H. Tuck

COMMITTEE ON LIGHTING OF CENTRAL STATION PROPERTIES

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*Approved by the I.E.S. Council, October 1950.

1. Introduction

1.1—*Basis of Report*—This report is based on the latest available engineering data, supplemented by a nationwide survey of existing installations. Since control rooms vary in design and function, and are not built to standardized patterns, no detailed design information is given. However, a comprehensive analysis of the lighting fundamentals is included together with a pictorial record of several different types of typical installations. These data, together with the analysis of the lighting problem which constitutes the body of the report, will guide the engineer in preparation of a satisfactory lighting design.

2. Seeing Tasks

2.1—*Basic Requirement*—(a) The importance of the subject of control room lighting has become increasingly greater due to the trend toward centralized operation (where nearly all equipment in a large plant is controlled from one room), and also to a more extended use of automatically operated equipment which requires that visual indications of a great many plant operations be available in the control rooms.

(b) The basic objective of the lighting engineer in designing control room lighting is to provide adequate and comfortable illumination on the instruments and other control devices on the switchboard. This involves more emphasis on vertical plane lighting than is usually encountered in design of interior illumination. Thus, control room lighting assumes a category entirely different from most other types of "room" lighting.

(c) Mere footcandle values must be subordinated to other objectives such as clear visibility of instrument scales free from reflected glare and shadows, uniform illumination on the switchboards without disturbing contrasting brightnesses, and glareless room illumination. If the lighting of the control room is properly designed with adequate vertical levels, the horizontal illumination will, in most designs, require little special attention.

2.2—*Basic Problems*—The basic requirement of emphasis on vertical plane rather than horizontal plane lighting for control rooms creates problems that are major issues in the practice of control room lighting. These problems can, in general, be classed:

(a) Contrasts or brightness difference in surrounding surfaces.

(b) Direct glare from light sources in the operator's field of vision.

(c) Specular reflection in the glass faces of the instruments (veiling glare).

2.2.1—*Factors Affecting Basic Problems*—The basic problems vary in relation to the types, heights and configuration of switchboards, room proportions, viewing position of personnel, types and sizes of instruments, color and type of instrument scales and size of lettering, and architectural and brightness balance considerations of the room, involving paint finishes, types and location of structural materials such as doors, windows, glass block panels, etc.

2.3—*Brightness Contrasts*—The problem of brightness contrast between light and dark surfaces can usually be solved by painting all surfaces light tints having suitable reflectance characteristics to produce low brightness contrasts. This, of course, includes the switchboards. A finish having high diffuse reflectance should meet the illumination design requirements. Light colored floors will add materially to

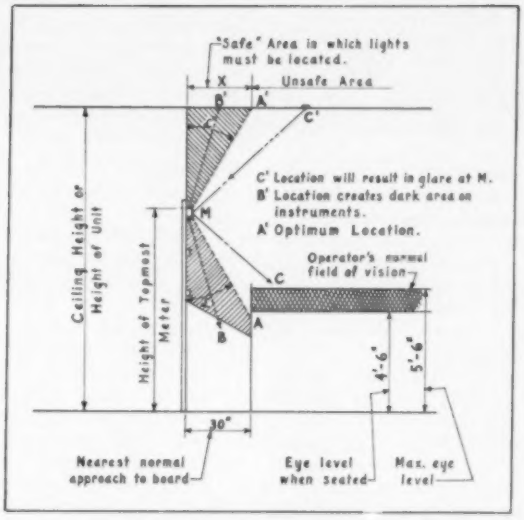


Figure 1. Location of direct units to maintain angle of incidence of fixtures equal to the observer's eye to avoid reflection in operator's field of vision.

the over-all effectiveness of the lighting system. Finishes having high specular reflection characteristics should be avoided in the control room.

2.3.1—*Color Scheme*—Too little attention has been given in the past to the color scheme in control room design. Some color tints, preferably pastels, worked into the general room design, will break monotony of color and create a more pleasant working environment.

2.3.2—*Finish of Instrument Cases*—Instrument cases should be finished to provide satisfactory contrasting hue to that of the switchboard, as a contrast is desirable to assist in natural focusing of the operator's eye on the scale to be observed. Such contrast is easily obtained from shades of colors without the extreme in contrast obtained from totally black trims.

2.3.3—*Reflecting Surfaces*—The eyes of operators and other workers in the control room are conditioned by the light coming from the reflecting surfaces of walls, furniture, switchboards and floors. It is therefore important that the brightness of the desk and the control board be at least equal to that from these surrounding surfaces. Every part of the surrounding surfaces should have favorable reflection factors. (See Table I.)

2.3.3.1—*Reflection Factors*—The approximate values of reflection factors that have been found to give satisfactory results are listed in Table I.

TABLE I.—Reflection Factors.

	per cent
Ceiling	80
Walls	50
Switchboard	50
Desk	35
Floor	25

2.3.3.2—*Furniture Finishes*—Glass top and highly polished desks should not be used. All furniture finishes should have favorable reflection factors and should harmonize with the color scheme of the room.

2.4—***Direct Glare***—Elimination of direct glare from areas of high brightness in the field of vision is extremely important, as this is a common cause of eyestrain complaint and inability to see clearly. Careful location of light sources, luminaires, and windows with respect to the operator's field of view, and shielding arrangements such as recessing, tilting, or louvering should be utilized to eliminate this problem.

2.5—***Reflected Glare***—Light reflection from instruments (veiling glare) is a most difficult problem to solve. Any source of light for switchboard illumination may be reflected in the glass faces of the switchboard instruments. If this is a source of high brightness, the angle of incidence should be greater* than that of the line of sight of the operator whether seated or standing in front of the switchboard (Fig. 1), so that light reflection will be out of the operator's field of view. When this is done, there is no problem of instrument glare when viewing the instruments directly from in front of board. If the source of ceiling brightness reflected by the glass cover is substantially less than the brightness of the instrument scale and it is uniform (without sharply defined pattern), then the veiling glare effect on visibility of the scale is largely mitigated.

2.5.1—*Windows*—Windows provided for daylighting, ventilation, or for psychological reasons, present a special problem because of their usual location in the side walls of the control room. Some form of control device must be provided for any window areas which are so located that they might become glare sources. The venetian blind is not entirely adequate for this purpose because of the distinct brightness pattern inherent in this type blind. Ordinary opaque window shades appear to be a practical means, although fire-proof draw curtains may prove the most effective.

2.5.2—*Shadows on Instrument Scales*—When the light source is placed close to the vertical face of the switchboard to obtain a satisfactory angle of incidence, this will in many cases produce some shadows on the instrument scales, and to some degree reduce visibility of switchboard name plates.

2.5.2.1—*Special Case Construction*—The shadows on the scales of modern instruments can be substantially eliminated by utilizing instruments having all sides of transparent material (Fig. 2), or having portions of the tops of glass or plastic (plain or refracting) to admit light on the upper parts of the scale (Fig. 3), or of other special construction (Fig. 4).

In some cases where this type of construction has been employed, additional visibility has been secured by tilting the instruments, instrument covers, or the tops of the boards, thus reducing veiling glare. Shadows have been reduced in some designs of instruments by moving the scale closer to the cover glass.

*The angle of incidence of light is by definition the angle between the perpendicular to the surface and the line of incidence of the light.

2.5.3—*Reflection in Instrument Trims* — Switchboard designers should be warned agninst accepting highly polished chrome or other specular finished instrument trims that produce annoying specular reflections or highlights.

3. Corollary Factors

3.1—*Indicating Lamps* — The indicating lamps on the switchboards must be of sufficient brightness to provide visibility but they should not be bright enough to become a source of reflected or direct glare. The switchboard designers should carefully check the brightness of the lamp assembly required for the vertical level of illumination established for the switchboard

3.2—*Size of Scales and Lettering* — Size of instrument scales and lettering on the scales is an important factor in seeing. The size of scales and letters should be coordinated with the maximum distance of viewing. Many operators feel that 4-inch scales and ¼-inch letters are ample to show approximate values of readings from any distance in the average control room, on the basis that ability to read instruments with fine accuracy is not required except when operator is recording readings from viewing distances close to the board. Others establish 7-inch instruments as the preferred minimum size for large control rooms so that reasonably accurate readings may be obtained from desks. In any case, white scales with black letters are recommended for good visibility, greatest comfort, and minimum reflection in the glass fronts.

3.3—*Name Plates*—Like instrument scales, the name plates should be white background, with black letters. Several types of plates are commercially available that will accomplish this result.

3.4—*Non-Glare Glass*—Instruments may be equipped with non-glare glass for reducing annoying reflections. This construction is quite effective in bench board instruments. However, it is seldom necessary in vertical instruments when a well-designed lighting system is installed. Certain types require special maintenance.

3.5—*Internal Illumination for Instruments*—Since highlights from the glass fronts of instruments do not reduce visibility greatly if the illumination on the scale is substantially greater than that of the reflection in the glass from the external light source, some designers have preferred to apply internal scale lighting to the instruments. However, if the general illumination on the board is of satisfactory value, it would appear that supplementary internal lighting would not be required. Further, internal light sources in one instrument of a duplex rectangle or long parallel design can cause annoying reflection in boards on opposite sides of the control room. Also, the added heat in the instrument and the additional wiring required may become a problem to the switchboard designer.

4. Control Room Arrangements

4.1—*Switchboards* — **(a)** The layout of the control room materially affects solution of the problem (Fig. 5). Arrangements of switchboards (for convenience in reference through this report) can be classed as:

(1) Simplex—A single line of panels (straight or curved) facing one side only.

(2) Duplex—A single line of back to back panels (straight or curved) forming a cubicle when ends are closed.

(3) Simplex Angle — Two or three single lines of panels each at right angles to the next.

(4) Duplex Angle — Two or three double lines of panels, or cubicles, each at right angles to the next.

(5) Simplex Rectangle—Four lines of panels forming a rectangle, "walling in" the operator in the center.

(6) Duplex Rectangle—Four lines of panels, or cubicles, forming a rectangle, "walling in" the operator in the center.

(7) Long Parallel — Two rows of panels facing each other across a narrow aisle of a long control room.

(8) Bench Boards—A switchboard in the form of a table or bench, which may or may not be attached to the vertical panels.

(b) Duplex panels are sometimes open between front and back panels, and sometimes entirely enclosed. Con-

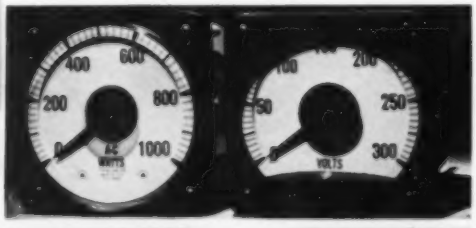


Figure 2. Improved design of instrument front, left. Note elimination of shadow on scale of instrument at left by means of rounded edge feature of glass face which admits light to upper part of scale.

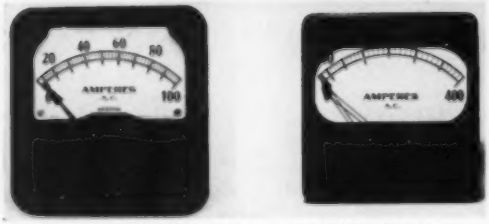


Figure 3. Modified instrument case design, left, to provide clear opening at top of scale to admit maximum light and eliminate shadow.

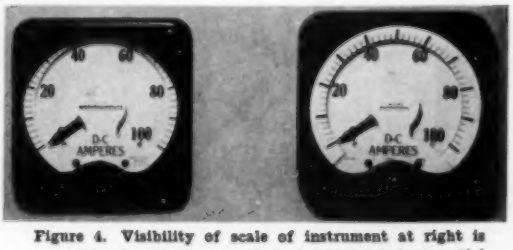


Figure 4. Visibility of scale of instrument at right is materially improved over that at left by bringing dial edges out to glass and sloping them to reduce shadow.

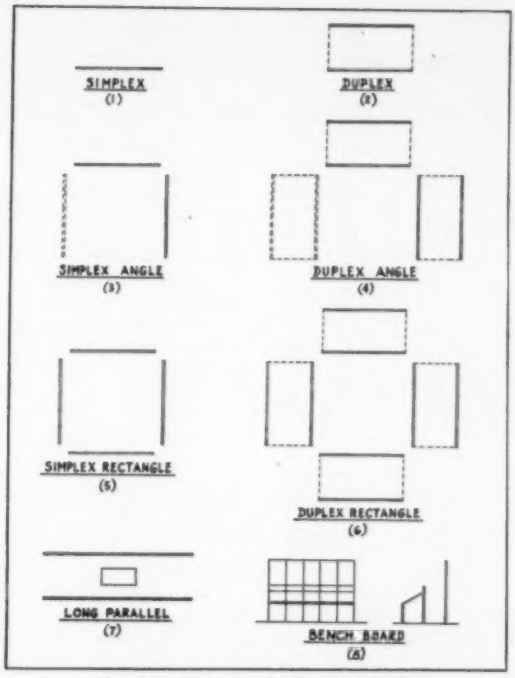


Figure 5. Arrangements of switchboards.

trol rooms may be long and narrow or varying in rectangular form to a perfect square. In some instances, they have been of odd shapes, and may involve combinations of the above types. Ceiling heights, especially in relation to length and breadth of the room, materially affect the lighting problem.

(c) The seeing task is greater in the very large control room, designed for centralized operation of a complete plant, than it is in a small control room containing controls of less importance. For this reason control rooms are considered to be in two general categories in this report:

Type A—Large control rooms containing controls for centralized operation of most plant functions, and requiring critical seeing.

Type B—All other types of control rooms.

4.2—*Desks*—As previously stated, the important and basic objective in control room lighting practice is to provide adequate seeing of instrument scales and switchboard name plates. An illumination level on the operator's desk approximately equal to that on the vertical face of the switchboard will be found adequate to provide for the normal seeing tasks on the desk. Great differences in brightness between instruments and work on the desk are undesirable as it is necessary for the operator to be able to glance from his desk work at any time to observe approximate indications of certain instruments.

4.3—*Bench Boards*—The problem of bench boards is not serious unless they are equipped with instruments. In this case reflections might be bothersome from louvered luminous or simple direct lighting systems. The direct controlled systems (discussed in Section 6.2) can be designed to eliminate the reflection in bench board instruments by proper location of fixtures. Care must be used in selection of the lighting system that the system selected does not create a noticeable reflection pattern in the bench board instruments. The bench board with instruments is one application for a suitable anti-glare glass. In general, the bench board can be treated as a desk in the solution of the lighting problem, except that the visual task is usually less severe on the bench board than the desk, where reports and charts are sometimes prepared.

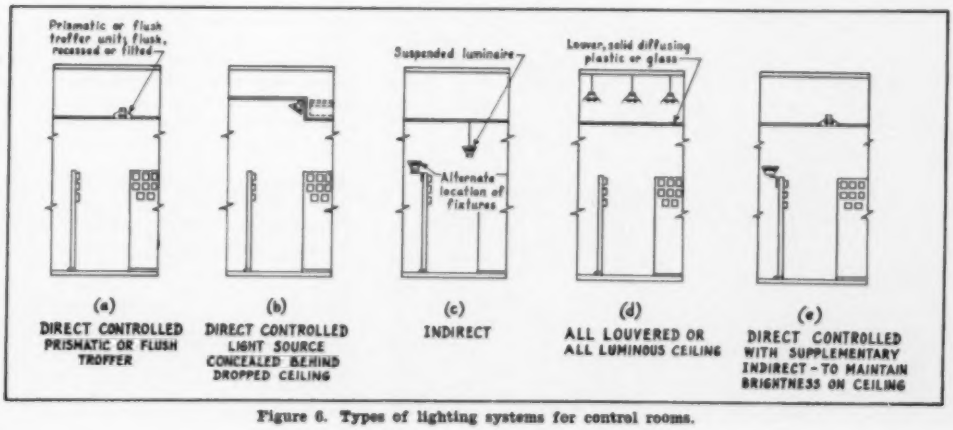

Prismatic or flush troffer units flush, recessed or lifted
Suspended luminaire
Alternate location of fixtures
Louver, solid diffusing plastic or glass
(a)
DIRECT CONTROLLED PRISMATIC OR FLUSH TROFFER
(b)
DIRECT CONTROLLED LIGHT SOURCE CONCEALED BEHIND DROPPED CEILING
(c)
INDIRECT
(d)
ALL LOUVERED OR ALL LUMINOUS CEILING
(e)
DIRECT CONTROLLED WITH SUPPLEMENTARY INDIRECT - TO MAINTAIN BRIGHTNESS ON CEILING

Figure 6. Types of lighting systems for control rooms.

5. Recommended Illumination Levels

5.1—Recommended illumination levels are given in Table II.

TABLE II. — Lighting Levels at the Work — Instrument Level.
(Maintained in Service)
Current Recommended Practice

Locations	Footcandles
Vertical Face of Switchboards —	
Simplex or section of duplex facing operator (Type A—large centralized control room 86 inches above floor)	50
Simplex or section of duplex facing operator (Type B—ordinary control rooms at 86 inches above floor)	30
Section of duplex facing away from operator	25
Bench Boards (Horizontal Level)	30
Desk (Horizontal Level — critical seeing tasks)	50
*Desk (Horizontal Level — ordinary seeing tasks)	30
Area Inside Duplex Switchboards (Horizontal) (1' 0" Above Floor)	5
Rear of all Switchboard Panels (Vertical)	10
Emergency Lighting All Areas	3

(Types of control rooms are defined in Section 4.1 (e).)

*See "Recommended Practice of Office Lighting."

6. Effective Designs

6.1—***General Classifications***—Lighting systems for control rooms may be divided into two general classifications (Fig. 6):

(1) Direct Lighting (6.2)—A system very accurately designed to control and distribute the light on the face of the panels, to eliminate glaring reflections on the instrument faces. Additional general room lighting should be provided to supplement the localized control lighting of the boards. Provision should be made in the design of any direct lighting system to insure suitable ceiling brightness.

(2) Luminous Ceiling (Including Indirect) (6.3)—A system designed to use the ceiling as a large area light source. There is no accurate control of light on the switchboard, but it is essential to control the brightness distribution in such a manner that there will be no objectionable reflection from the instrument faces and no discomfort from glare originating from the general lighting system.

6.2—***Direct Lighting*** — There are three general types of direct lighting systems:

(a) Prismatic lens control (6.2.1)
(b) Flush troffer system (6.2.2)
(c) Dropped ceiling (6.2.3)

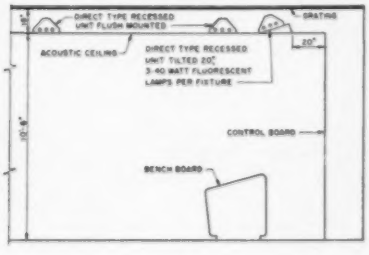
6.2.1—*Prismatic Lens Control*—Many control rooms have successfully used a type of lighting system in which the light flux is very accurately controlled by means of prismatic lenses designed for this specific purpose (Fig. 7). This local lighting of the board is supplemented by general room lighting, the character of which may vary widely to meet individual requirements. Because of the very accurate control exerted with this type of equipment, it is desirable that the design should be prepared by engineers thoroughly familiar with its use in order to minimize reflections in instrument cases and shadows on instrument scales.

6.2.2—*Flush Troffer System*—Another type of direct lighting which is being widely and successfully used utilizes flush type troffer units, accurately placed to control distribution of light on the surface of the instruments and panels (Fig. 8). Quite frequently the equipment used in this system consists of metal parabolic reflectors housing fluorescent lamps, mounted flush with the ceiling, and enclosed on the surface with a louver system designed to minimize reflected glare in the instrument faces. With this arrangement the same general type of equipment is quite frequently used for the general room lighting. In some cases downlights have been used to supply illumination at the operator's desk.

6.2.3—*Dropped Ceiling* — This design (Fig. 9) is a modification of the flush troffer system utilizing a dropped ceiling in the center portion of the room. The purposes of this depressed section are to shield the fixtures from the view of the operator, eliminating the possibility of reflection in instrument boards on opposite sides of the room and providing an additional diffused reflecting surface which would direct light, otherwise projected into the control room, towards the switchboard. This diffused component helps reduce shadows on the control board.

6.2.3.1—*Board Lighting Units* — The lighting units used may be prismatic, open, or louvered troffers but for maximum advantage the location of fixtures and the design of the dropped

Figure 7. Direct board lighting from recessed prismatic units, producing 45 footcandles vertical illumination at top of board and 20 footcandles horizontal illumination at desk level.



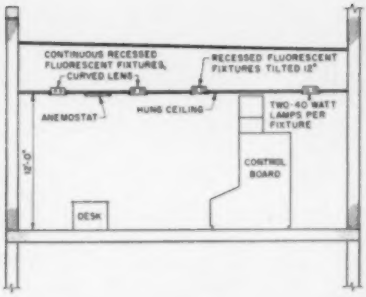
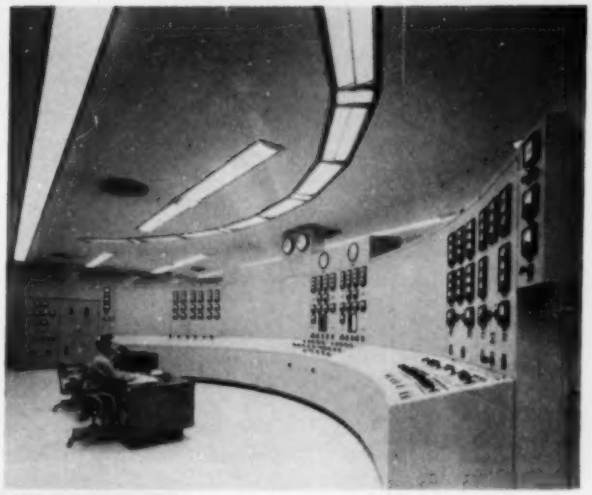
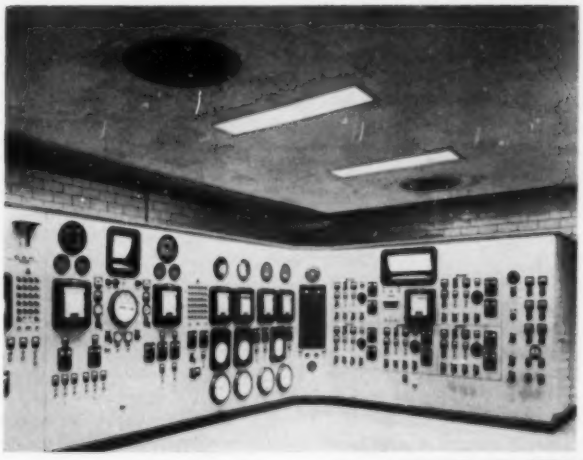


Figure 8. Direct board lighting from recessed troffers with curved prismatic lens in a flat ceiling, producing 32 footcandles vertical illumination at top of board and 40 footcandles horizontal illumination on bench board.





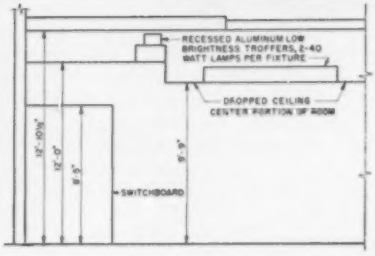
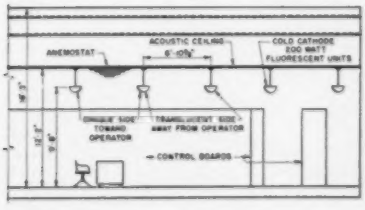


Figure 9. Direct board lighting from troffer units concealed behind a dropped ceiling. (Illumination levels for this control room are not available.)

Figure 10. Indirect design with partial direct illumination on panels afforded by utilizing suspended luminaires with translucent side facing control boards, and opaque side facing operator, producing 28 footcandles vertical illumination at top of board and 36 footcandles horizontal illumination at desk level.



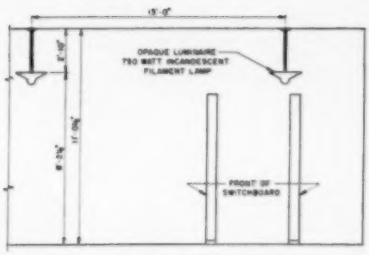


Figure 11. Totally indirect design using suspended luminaires, producing 13-15 footcandles vertical illumination at a height of five feet and 21 footcandles horizontal illumination at desk level. A feature of this installation is the successful repainting of an existing black switchboard an opalescent gray (aluminum) lacquer.

section of the ceiling must be coordinated with candlepower distribution of the luminaire. Low luminaire brightness is also desirable.

6.2.3.2—*General Lighting*—For maximum advantage the center portion of the room should utilize low brightness troffers so positioned that reflections from instruments on the board will be minimized.

6.2.4—*Combinations* — Direct schemes are sometimes employed for switchboards in combination with indirect for general room illumination (Fig. 10).

6.3—***Luminous Ceiling Lighting*** — The effect of a luminous ceiling may be obtained in one of three ways:

(1) Indirect (6.3.1)
(2) Louverall (6.3.2)
(3) All Luminous (6.3.3)

6.3.1—*Indirect*—Indirect systems (Fig. 10 and 11) utilizing the ceiling as a secondary light source are as follows:

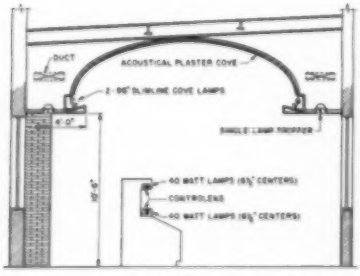
6.3.1.1—*Suspended Luminaires*—Luminous indirect luminaires having an upward light component of 90 per cent or more provide one satisfactory method of lighting control rooms. For best results the brightness of the luminaire should approximate the brightness of the ceiling. Equipment location should be carefully planned to reduce annoying reflections in the instrument faces to a minimum. The ratio of vertical to horizontal footcandles has been found in practice to vary from 1:3 to 2:3.

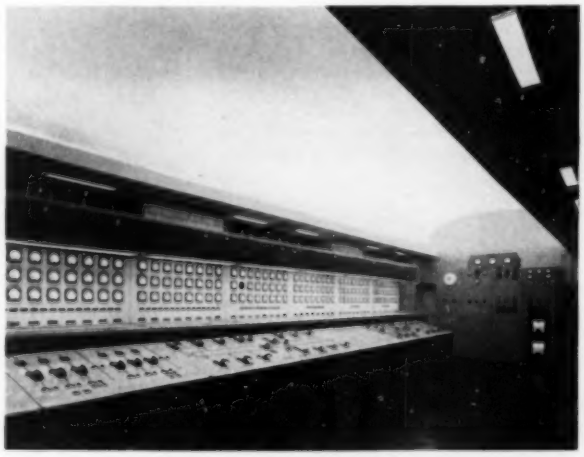
6.3.1.2—*Totally Indirect*—In the case of switchboards closely spaced, some installations have successfully used opaque indirect reflectors mounted on top of and immediately behind the panels with the light directed to the ceiling. This type of installation would be successful only in the case of simplex or duplex switchboards closely spaced. In some cases this has been supplemented by louvered troffers mounted close to the ceiling.

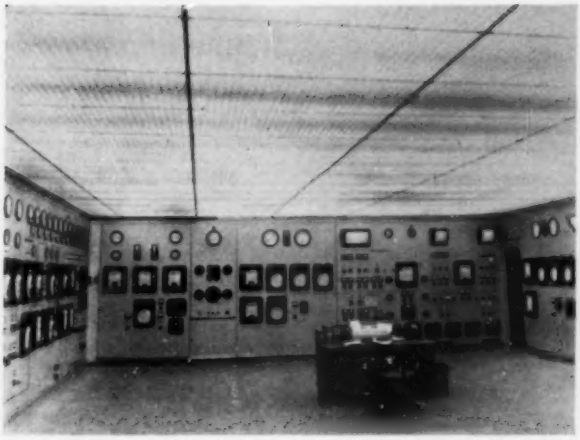
6.3.1.3—*Ceiling Configurations* — The indirect scheme sometimes takes the form of curved or parabolic ceilings or coves in an effort to increase the vertical component of light on the meter face. (See Figs. 12 and 14.)

6.3.2—*Louverall Ceiling*—One form of the luminous ceiling is the louverall type (Fig. 13 and 14), utilizing eggcrate louver construction over the en-

Figure 12. Combination indirect cove-type lighting for general illumination with supplementary direct illumination from top and bottom of panel, producing 60 footcandles vertical illumination at top of board and 32 footcandles horizontal illumination at desk level.







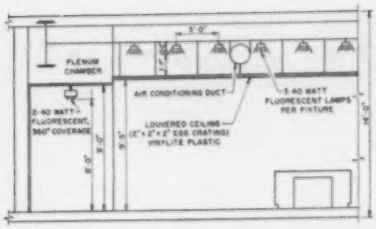

PLENUM CHAMBER
AIR CONDITIONING DUCT
3-40 WATT FLUORESCENT LAMPS PER FIXTURE
2-40 WATT FLUORESCENT, 360° COVERAGE
LOUVERED CEILING (2" x 2" x 2" EGG CRATING) VINYLITE PLASTIC

Figure 13. Louverall with 2" x 2" x 2" plastic eggcrate construction, producing 45 footcandles vertical illumination at center of board and 120 footcandles horizontal illumination at desk level.

tire ceiling with luminaires placed above the ceiling. This design has been effectively used to provide high intensity vertical plane illumination with low glare rating. Such design usually results in a much higher horizontal than vertical illumination level, a value in most designs in the order of 1 to 3 ratio of vertical to horizontal footcandles. The open louvers greatly facilitate diffusion of ventilating air, especially in air conditioned rooms, and the design lends itself readily to acoustic treatment.

6.3.2.1—*Dimensions* — Eggcrate louver cells may be of any size but a minimum shielding of 45 degrees is recommended.

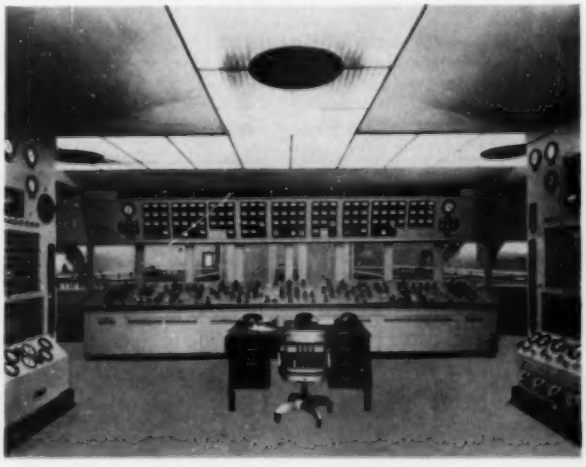
6.3.2.2—*Material*—The louver material may be aluminum, painted metal, or plastic. It is recommended that the material used be of a type that will not support combustion. The opaque type louvers tend to present more of a pattern effect than do the translucent in the trace of ceiling reflection that is normally noticeable in instrument fronts under louverall ceilings.

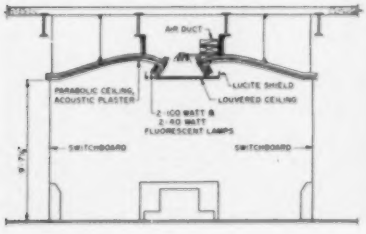
6.3.2.3—*Louver Finish*—A matte louver finish will give greater diffusion than a specular finish. Likewise, it will have a wider distribution than the specular finished louver. While the matte finish will have greater brightness, this system easily produces high illumination levels with direct glare held to comfortable values.

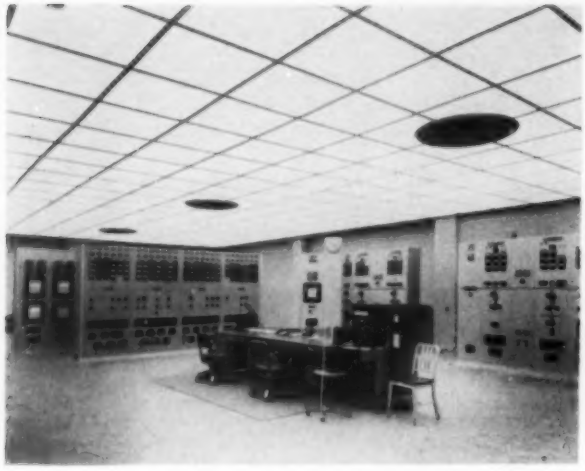
6.3.2.4—*Lamping*—In the lamping area above the louvers, either bare lamps or reflectors can be used, with all cavity surfaces painted white for maximum reflection. The ratio of spacing of lamp units to distance above louvers should not exceed $1\frac{1}{2}$:1 for uniform ceiling brightness. If plastic louvers are used, emergency incandescent filament lamps should be located high enough above the ceiling to avoid excessive heat on the louvers.

6.3.3—*All Luminous Ceiling*—Another form of luminous ceiling is the solid ceiling constructed of a diffusing transmitting medium of either plastic or glass, with light sources mounted above (Fig. 15). This type of construction makes possible a high degree of diffusion on both the vertical and horizontal planes. It is recommended that no material be used that will support combustion.

Figure 14. Combination indirect (parabolic ceiling) and louverall ceiling, producing 50 footcandles vertical illumination at top of board and 50-60 footcandles horizontal illumination on the bench board. Instruments in background are tilted toward observer and have transparent top section to admit light to scales and eliminate specular reflection in the instrument fronts.







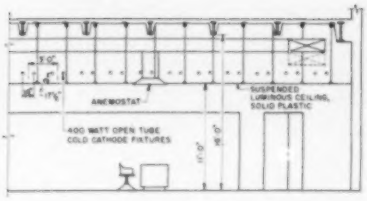


Figure 15. Solid diffusing plastic luminous ceiling producing 18 footcandles vertical illumination at top of board and 45 footcandles horizontal illumination at desk level.

6.3.3.1—*Architectural Relation*—From the nature of the system, such an installation becomes a part of the architecture of the room and should be designed to blend with the other requirements such as ventilation and soundproofing.

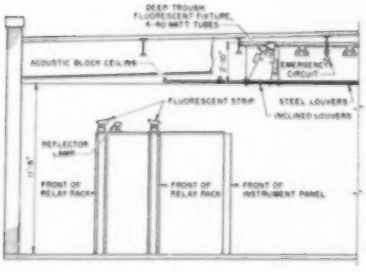
6.3.3.2—*Material*—Material for all luminous ceilings may be diffusing plastic or glass. If diffusing plastic is used, there is a tendency for the plastic to become electrostatically charged and collect dust. It is recommended that no material be used which will support combustion.

6.4—*Inclined Louvers* — Louvers adjacent to the switchboards may be inclined to admit maximum light from the overhead source to the top sections of the panels (Fig. 16). Illumination levels can be increased at these areas by employing lighting units designed and located to direct their beams to the switchboard face.

6.5—*Back of Board Lighting*—Back of board lighting for simplex boards (or interior lighting for cubicles) has in too many instances been entirely neglected. Maintenance and inspection work behind the panel fronts require good lighting. This can be a scheme employing one or two fluorescent tubes in a continuous row at the panel top giving 360-degree coverage in the case of cubicles, or a line of diffusing or prismatic glass incandescent units, one to a panel. Even though high intensity general room illumination is installed, structural and other interferences between front and rear rows of panels may require that "back of board" illumination be provided.

6.6—*Relighting Existing Control Rooms*—(a) The principles for relighting existing control rooms are not much different from that of lighting new control rooms. However, the problems faced by the lighting engineer may be severely aggravated by structural or other difficulties such as odd room proportions in the older installations. Rehabilitation of existing control room lighting may call for special study.

Figure 16. Louverall ceiling with portion of louvers inclined toward panels, producing 40 footcandles vertical illumination at top of board and 30 footcandles horizontal illumination at desk level. Instruments have transparent tops to admit light.



(b) If the project of relighting the older control room is approached on the same basis as in the case of a new job, the same results will be accomplished. Backgrounds and the panels themselves can be repainted in light colors. (See Fig. 11a.)

6.7—*Emergency Lighting* — Some form of emergency lighting is usually felt to be desirable in control rooms, although this might not be necessary in rooms with interspersed circuits from several sources of power. Where the control room is lighted from only one or possibly two sources, emergency lighting from storage batteries or internal combustion driven generating sets is desirable. Emergency lighting should be incandescent for quick response in the emergency and need be only sufficient to enable an operator to perform all the functions required of him in an emergency. Usually 3-footcandle illumination on vertical faces of boards has been found sufficient for emergency operations.

6.8—*Canopies* — Canopy type direct lighting is used on local or remote boards in the plant where the ceiling is too high or where unsuitable construction precludes use of other types of lighting. This construction is not recommended for control rooms.

7. Design for Daylight

7.1—*Daylight as Source* — Dependence cannot be placed upon daylight as a primary source of illumination since control rooms must operate 24 hours each day of the year. There is also the major problem of switchboards forming barrier walls to block out light sources and create uneven brightness levels throughout the room. However, some operators prefer to take advantage of daylight where possible and the architectural design includes daylight provisions in these cases.

7.2—*Location of Light Source*—Extreme care must be used in locating windows of control rooms to minimize direct glare in the operator's eyes and reflections on switchboard instruments. For long parallel switchboard configuration, the boards can sometimes be located at right angles to the light sources. In case of simplex rectangle or duplex rectangle, the problem is more complicated, and special light controls, such as dark blinds or draperies might be necessary. Translucent blinds must be avoided as they will not eliminate the reflections.

7.3—*Glass Blocks*—Glass blocks present essentially the same problem as clear windows except that more effective use can be made of the daylight by use of prismatic designs that direct the light upward to reduce glare and provide improved distribution of light.

Appendix A — Other Factors Influencing Lighting Design

A-1—*Ventilation*—Ventilation of operating rooms is related to the lighting problem in several ways. If a louverall ceiling is utilized, the area above the ceiling can be used for ducts that distribute the cooling air, which will be diffused through the louvers. For any false ceiling design utilizing direct, indirect or solid ceiling lighting scheme, ventilating diffusers or their equivalent are required and in the case of luminous ceiling or indirect ceiling, these should be so placed that their contrast against the ceiling surround is out of the operator's field of vision and does not create brightness difference reflection in the instrument faces.

A-2—*Acoustic Treatment* — Where the requirements are such that acoustic treatment is desirable, this condition should be considered in the selection and design of the lighting system.

A-3—*Architectural and Mechanical Design*—In new designs the architectural and mechanical design and installation should be closely coordinated to provide room for electrical fixtures and to simplify the lighting job to the greatest extent possible.

A-4—*Conduit and Wire* — Designers should be liberal in conduit and wire sizes in the initial installation to accommodate possible future changes and additions.

A-5—*Switchboard Devices*—Visibility of switchboards in general is much improved with the use of flush type devices. Manufacturers of switchboard instruments should review the design of their line with a view to furnishing all instruments with glass covers or at least glass tops to provide maximum illumination on the scales for mitigating glare and eliminating shadows. It is also suggested that they consider the use of high reflectance matte finishes for instrument cases in suitable contrasting colors as standard practice.

Appendix B — Case Histories

B-1—*Summary of Case Histories*—In order to obtain some cross section of current practice in control room lighting, a questionnaire was submitted to 44 operating companies and consulting engineers and 37 replies have been received giving information on 47 control rooms, most of which are recently constructed installations. The following is a condensation of this information:

Number of companies contacted	44
Number of companies replying	37
Number of companies reporting information	33
Number of installations reported on	43
Number of control rooms reported on	47
Number of companies not indicating that company name may be used	15
Type of Illumination:	
Direct	17
Semi-direct	7
Semi-indirect	1
Indirect	8
Louverall	6
All luminous plastic ceiling	1
Combination of several types	7
Type of Lighting Units:	
Fluorescent	36
Incandescent Filament	8
Combination	3

Lighting Results:	**Average Value**	**Range of Values**
Vertical Footcandles, Top of Board	36.1	8 to 90
Vertical Footcandles, Bottom of Board	22.5	4 to 75
Horizontal Footcandles at Desk Level	45.9	8 to 150
Watts/sq ft of floor area	4.7	1.45 to 13

Of the 47 control rooms, eight have not been completed so that their figures are design figures, not measured values. Of control rooms in service, the maximum illumination measured at the bottom of the board was 52 footcandles.

Control Room Colors:

Color of walls—mostly buff or cream with remainder either gray or green.

Color of ceiling—white in practically all cases.

Color of floor—mostly marbleized tile flooring of gray, brown, or green.

Color of boards—about ⅔ are gray, nine are black, four are eye-rest green, one is buff and one is blue green.

Color of desks—gray, green and oak.

Lighting behind boards or inside cubicles: Where supplementary lighting is used behind boards or inside cubicles, in most cases it is supplied by bare incandescent filament lamps.

Emergency lighting: In practically every case, the emergency lighting units are incandescent filament lamps controlled by an automatic throw-over switch which automatically throws on the d-c supply in case of a failure of the a-c supply.

In three cases, the emergency lighting is supplied by an a-c source. In another case, the direct lighting is on one service and the indirect on another with both services normally on.

Remarks: Only one company reported the use of dimmers. The lighting in this control room is fluorescent for general illumination with panels lighted by direct incandescent filament lamps. Two separate dimmers are used—one for the fluorescent lighting and one for the incandescent lighting.

Of the 39 control rooms which are completed, 35 are reported as having satisfactory lighting.

One company reports that in order to make the lighting satisfactory, antiglare glass must be installed on the instruments to avoid images of luminaires being visible on instrument faces.

Another company reported that its lighting is also unsatisfactory because of reflected glare from the instrument faces. In addition, this company reports that the level of 12 footcandles on the desk top is insufficient.

Another company reported that its operators generally turn off the direct lighting on the face of the boards because of the excessively high intensity. This same company also reports that the satin chrome control knobs which they use on their control boards pick up high lights causing glare. These high lights, however, do not occur on the instrument faces.

One company having a ceiling of dark gray acoustical material reported that the ceiling should have been of a light color rather than the dark gray.

One company having black control boards reported that it expected to paint them a silver gray lacquer or similar finish.

Appendix C — Maintenance

Since the lighting systems of control rooms are in continuous operation the problem of lamp depreciation is quite serious. Where incandescent filament sources are used normal operation would require nine lamp changes per year. For this reason the collection of dust and dirt on lamps and equipment is not serious if the lighting equipment is cleaned when lamps are replaced. Modern luminous tube sources may have a life of 7000 hours or more. In order to maintain a satisfactory illumination level it will be necessary to establish regular cleaning dates between lamp changes. In any case some form of group replacement is recommended. A thorough cleaning of all lighting equipment at not greater than three-month intervals is recommended to insure operating efficiency. Where the room is completely air conditioned, a maintenance schedule of six months may be satisfactory.

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Reprints of "Lighting of Control Rooms" will soon be available in booklet form. This report, prepared by the Subcommittee on Control Room Lighting of the Committee on Lighting of Central Station Properties, will contain, in addition to the material given here, complete tables giving the details of the case histories on the 47 control room installations. Single copies $0.50, quantity prices upon request.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Washington, D. C.—Site of I.E.S. National Technical Conference

Washington, the nation's capital, is your Conference City for 1951. Date of the conference—August 27 through 30—was set up to afford delegates an opportunity to enjoy a long weekend holiday after the four days of technical papers.

This year, a grand total of 47 papers is planned, making it necessary that all sessions be parallel. A mailing is in process to members of the Society giving the program for the technical sessions.

Aside from the serious business which is the purpose of the Technical Conference, Washington provides a wealth of educational pursuits, all disguised as entertainment and relaxation. Classical arts, physical sciences, government, history, religion — Washington can supply it, whichever your preference.

The Conference Committee has planned a program of entertainment starting the day you arrive.

Monday evening, August 27 — The Lighting Service Forum is scheduled for this evening in the Main Ballroom of the Shoreham Hotel. A most unusual program has been planned by the Lighting Service Committee, under the guidance of L. E. Tayler.

Tuesday evening, August 28 — A time to see your friends, attend the drama, "Faith of Our Fathers," or otherwise spend as you prefer. The Reception Committee will be glad to assist you in any way it can.

Wednesday afternoon, August 29 — "Cruising down the river" — for the entire family — an excursion down the Potomac to historic Mount Vernon. The three-hour trip on a streamliner excursion boat includes a stopover of more than an hour to be spent in the buildings and grounds of George Washington's country home.

For those who prefer golf, there is the competition for the President Law trophy on the National Capital open championship course of Prince George's Golf and Country Club.

Wednesday evening, August 29—Each year the Lighting Progress Report becomes more elaborate, more informative and more entertaining. This is a highlight which no one should miss.

Thursday evening, August 30 — President's Reception and Banquet is the climax of the Conference. There will be dinner and dancing under the stars on the Shoreham's terrace against a background of wooded Rock Creek Park and the illuminated fountain.

Especially for the Ladies

A series of programs, slanted to interest the women in your party, have been arranged which will keep them interested and busy during the technical sessions.

Sunday afternoon, August 26—a greeting party in the East Room of the hotel.

Monday, August 27 — A complete "highlight" tour of the City of Washington to see its important public buildings, historic shrines, famous churches, foreign embassies and beautiful parks.

Tuesday, August 28 — A visit to the Electric Playhouse, a small theater dedicated to electrical living, where a special program is planned for I.E.S. ladies.

In the afternoon, there will be a reception and tea at the home of the President

TWO OF THE MANY buildings of interest you will want to include in a tour of Washington, when you are there for the I.E.S. National Technical Conference.

SOME OF the local and National planners for the National Technical Conference, Washington, are, l. to r., R. F. Hartenstein, Chairman, National Technical Conference Committee; George W. Clarke, Chairman, Conference Executive Committee; Harry Grattan, Jr., Chairman, Committee on Attendance and Publicity; Hoyt P. Steele, Chairman, Papers Committee, and Walter Sturrock, National President, I.E.S.

of the United States where, if she can arrange it, Mrs. Truman will be hostess.

Wednesday, August 29—The Residence Lighting Forum meeting will appeal to all the women and they are urged to attend. In the afternoon is the cruise down the Potomac to Mount Vernon and a tour through the buildings and grounds.

Thursday, August 30—A technical session of the Residence Lighting Committee will be of interest to the women present.

In the afternoon, a tour of "Embassy Row" will give sightseers a visit to several of the embassies and legations on famed old Massachusetts Avenue.

BRING THE CHILDREN

An attractive club room will be provided, under adult supervision, for the teenagers. Plans are afoot for swimming, a wiener roast and an especially designed sightseeing trip.

SPORTS PROGRAM

Golf, riding, boating, swimming, tennis — sports are conveniently nearby to the Hotel Shoreham. Try your golf at the championship course of Prince George's Golf and Country Club. The President Law Cup will be at stake. Ride leisurely on shaded bridal paths through Rock Creek Park. A variety of boating facilities is readily available. Swimming and tennis at the Wardman Park Hotel.

The local Conference Committee urges you to plan your visit early.

Southeast Florida Chapter Host to Southern Regional Conference

A number of factors contributed to the outstanding success of the Southern Regional Conference this year. Location — Miami in early April. Program — an excellent technical session with timely important subjects and some of the country's leading speakers. Good planning — months of convention-type organization by all of the Sections and Chapters involved, and especially the host Chapter, Southeast Florida.

Registered attendance was 179, with members and guests coming from Louisiana, Mississippi, Alabama, Missouri, Tennessee, Georgia, the Carolinas, Florida, Cuba and Puerto Rico. Winner of the plaque awarded for miles traveled and members present in relationship to total membership, was the Student Branch of Mississippi State College, State College, Miss.

SPEAKERS' TABLE of the Southern Regional Conference, held at Miami Beach, Fla. April 9 and 10. L. to r., Alston Rogers, Chairman, Progress Committee; A. C. Bergh, General Chairman of the Conference; Mrs. Hibben; Walter Sturrock, President; William B. Shenk, Chairman; Sam G. Hibben, President-Elect; Mrs. Browder; Joe H. Browder, Vice-President, Southern Region; Mrs. Paslay; R. C. Paslay, Vice-President-Elect, Southern Region.

A special feature at the Monday luncheon was the presentation and description of the Society's new brochure "Contemporary Lighting in Modern and Traditional Interiors," by J. H. Blitzer of Lightolier Co. Inc., a member of the New York Section's Residence Lighting Forum.

The 16 mm film "Your Invitation to Washington" was shown before an appreciative audience, while book matches calling attention to the forthcoming National Technical Conference (August 27-30 in Washington, D. C.) were distributed throughout the Conference.

ENTERTAINMENT FEATURES

The location, of course—Atlantis Hotel, Miami, April 9 and 10, lent itself especially well to unusual entertainment features. Trips were arranged by the committee for deep sea fishing, ocean-seeing trips in glass-bottom boats, horse

racing, dog racing, Jai-Alai, southern show boat — and many other features typical of fun in Florida. Special shopping tours were arranged for visiting ladies, along Miami Beach's world famous "Lincoln Road."

A banquet and dance was held Monday evening, at which guest of honor was the President of I.E.S., Walter Sturrock. One feature, presented at the banquet session, and combining entertainment with education, was Alston Rodgers' now famous show "Parade of Lighting Progress."

TECHNICAL SESSIONS

An exceptionally fine technical program was presented at the Conference. Featured were:

MONDAY, APRIL 9 — MORNING SESSION
Chairman, Jack H. Murrah, Georgia Section
Address of Welcome—Morris N. Lipp, City Engineers, City of Miami Beach
Response—Joe H. Browder, Vice-President, Southern Region, I.E.S.
Our Society—Walter Sturrock, President, I.E.S.
Use of Aluminum Alloys for Lighting Standards & Bracket Arms—E. T. Wanderer, Aluminum Company of America
Outdoor Lighting Brought up to Date (Streetlighting, Floodlighting, etc.)—R. J. Swackhamer, General Electric Company.
Luncheon

AFTERNOON SESSION
Chairman, G. G. Harney, Carolinas Chapter
The Use of Thermoset Plastics in Lighting—M. R. Bigelow, Plaskon Division, Libbey-Owens-Ford Glass Company
Up to the Minute Lighting Practice with Lens Forms—H. L. Logan, Holophane Company, Inc.
New Concepts in Lighting for Merchandising—D. P. Caverly, Sylvania Electric Products, Inc.
Cocktail Hour

EVENING SESSION
Chairman, William B. Shenk, Florida Chapter
Banquet
1950-51 Parade of Lighting Progress—Alston Rodgers, General Electric Company
Dancing

TUESDAY, APRIL 10 — MORNING SESSION
Chairman, R. C. Pasley, New Orleans Section
Designing Downlighting for Commercial Interiors—E. D. Altree, Pittsburgh Reflector Company
Recessed Troffers Have Their Place—G. W. Beals, The Miller Company
Color Correction and Other Improvements Expand Mercury Lighting (Industrial Lighting & Streetlighting). Introduction by Sam G. Hibben, Westinghouse Electric Corp.; Lamp Demonstrations by J. D. Mitchell, Westinghouse Electric Corp.; Extraordinary Applications by E. C. Huerkamp, Westinghouse Electric Corp.
Luncheon

AFTERNOON SESSION
Chairman, A. C. Bergh, Southeast Florida Chapter
There is More to Florida than Meets the Eye—R. B. Roberts, Jr., Florida Power & Light Co.
Summation and Reports
Adjournment

ORGANIZERS

The smoother the Conference, of course, and the more effortless it seems to be run, the harder the Committee members have worked beforehand. The Southern Regional Conference was smooth. Credit for its success goes chiefly to:

A. C. Bergh, Chairman of the Southeast Florida Chapter, and Chairman also of the Conference Program and Publicity Committee
Wm. B. Shenk, Chairman of the Florida Chapter
Jack H. Murrah, Chairman of the Georgia Section
Furna E. Lott, Conference Chairman
Joe H. Akerman, Hotel Committee
Ollie F. Swanson, Finance Committee
A. L. Benoit, Entertainment Committee
R. T. Fennell, Transportation Committee
H. M. Rose, Registration
Mrs. A. L. Benoit, Reception Committee
Clyde V. Booth, Attendance Committee

(*Continued on page 9A*)

LIGHTING CALENDAR

Society Events

June 14, 1951 — Meeting of I.E.S. National Council, New York, N. Y.

August 27-30, 1951 — Illuminating Engineering Society, National Technical Conference, Hotel Shoreham, Washington, D. C.

September 8-13, 1952 — Illuminating Engineering Society, National Technical Conference, Edgewater Beach Hotel, Chicago, Ill.

Industry Events

June 7-8, 1951 — American Management Association Waldorf-Astoria Hotel, New York, N. Y.

June 11-15, 1951 — Second Annual Conference on Industrial Research, Columbia University, New York, N. Y.

June 11-15, 1951 — American Society Mechanical Engineers, Semi-Annual Meeting, Royal York Hotel, Toronto, Canada

June 13-15, 1951 — President's Highway Safety Conference, Interior Auditorium, Washington, D. C.

June 14-16, 1951 — National Society of Professional Engineers, Annual Meeting, Minneapolis, Minn.

June 18-20, 1951 — Annual Convention of the Canadian Electrical Association, Algonquin Hotel, St. Andrews, N. B.

June 18-22, 1951 — American Society for Testing Materials, Annual Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

June 25-29, 1951 — Summer General Meeting, American Institute of Electrical Engineers, Royal York Hotel, Toronto, Canada

June 25 - July 4, 1951 — International Commission on Illumination, Stockholm, Sweden

June 30 - July 7, 1951 — New York State Association of Electrical Contractors and Dealers Annual Convention, Saranac Inn, Saranac, N. Y.

July 2, 1951 — International Organization for Standardization, Geneva, Switzerland

July 2-4, 1951 — The American Society of Heating & Ventilating Engineers, Semi-Annual Meeting, Portland, Oregon

August 20-23, 1951 — Pacific General Meeting, American Institute of Electrical Engineers, Multnomah Hotel, Portland, Ore.

September 11-20, 1951 — Building Research Congress, London, England

September 17-20, 1951 — International Municipal Signal Association, 56th Annual Meeting, Mark Hopkins Hotel, San Francisco, Calif.

September 24-27, 1951—32nd Annual Meeting, Institute of Traffic Engineers, Ambassador Hotel, Los Angeles, Calif.

September 25-28, 1951 — Fall Meeting, The American Society of Mechanical Engineers, Minneapolis, Minn.

September 26-28, 1951 — Annual Meeting, Canadian Electrical Manufacturers Ass'n, General Brock Hotel, Niagara Falls, Ont.

October 1-3, 1951—Eastern Section, International Association of Electrical Inspectors, Chalfonte-Haddon Hall, Atlantic City, N. J.

October 8-12, 1951 — 39th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

October 9-10, 1951—National Farm Electrification Conference, Hotel Gibson, Cincinnati, Ohio

October 9-12, 1951 — National Electrical Contractors Associations, Annual Convention, Shoreham Hotel, Washington, D. C.

October 10-13, 1951 — The Electrochemical Society, Inc., Semi-Annual Convention, Statler Hotel, Detroit, Mich.

October 15-17, 1951 — International Association of Electrical Inspectors, Southern Section, 23rd Annual Meeting, Hotel John Marshall, Richmond, Va.

October 15-19, 1951 — Fall 1951 Convention of the Society of Motion Picture and Television Engineers, Hollywood-Roosevelt Hotel, Hollywood, Calif.

October 22-24, 1951—33rd Annual Meeting, American Standards Ass'n, Waldorf-Astoria Hotel, New York, N. Y.

October 22-26, 1951 — American Institute of Electrical Engineers, Fall General Meeting, Hotel Cleveland, Cleveland, Ohio

November 12-15, 1951 — National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

November 25-30, 1951 — Annual Meeting, The American Society of Mechanical Engineers, Atlantic City, N. J.

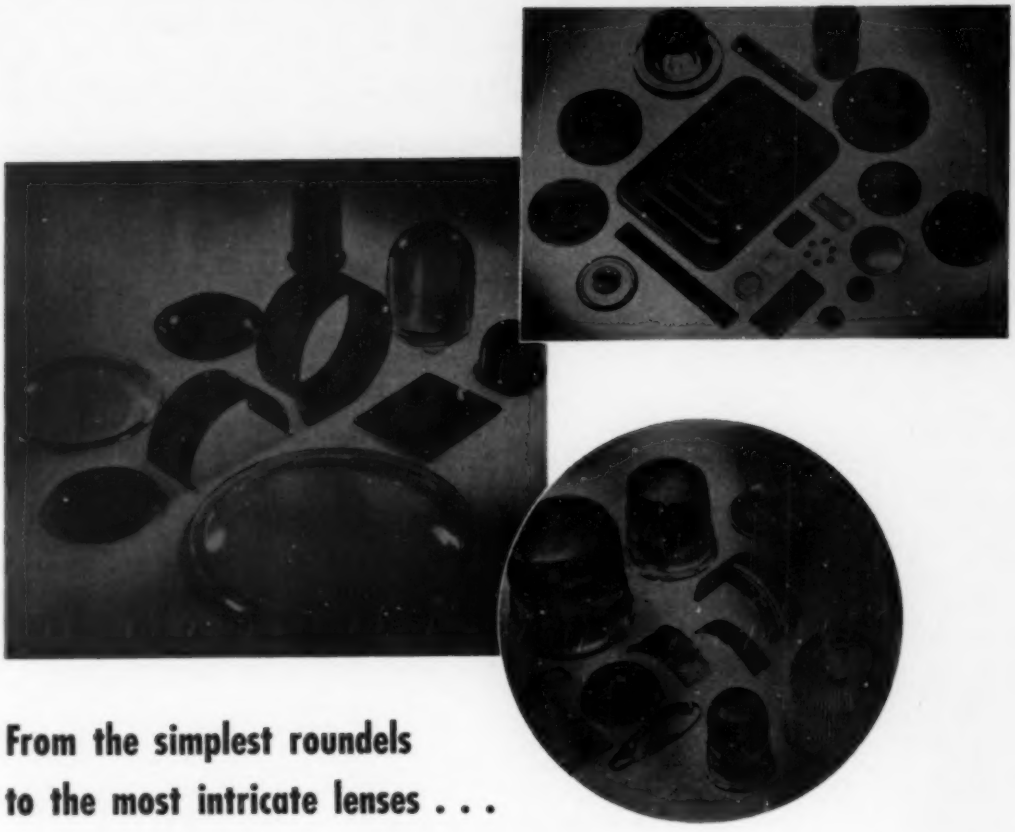
December 2-5, 1951 — American Society of Refrigerating Engineers, 47th Annual Meeting, Hotel Roosevelt, New York, N. Y.

December 5-7, 1951 — Annual Meeting, National Association of Manufacturers, Waldorf-Astoria Hotel, New York, N. Y.

Illumination Design-Courses Planned for Next Fall

A series of courses, planned to give the student an opportunity to make a detailed and complete study of the overall problems in design of illumination, is to be given next Fall, sponsored by the Spring Garden Institute of Philadelphia in cooperation with the Philadelphia Section of I.E.S.

Where feasible, the problems studied in class are followed by field trips where actual installations can be analyzed.



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(Continued from page 7A)

Subjects and speakers for the twenty sessions will be:

October 5—Light and Vision, C. L. Crouch, Technical Director, Illuminating Engineering Society
October 12—Light Sources (Incandescent, Arc and Mercury Arc), P. R. Holmes, General Electric Co.
October 19—Light Sources (Laboratory, Auxiliary Equipment, etc.), P. R. Holmes, General Electric Co.
October 26—Instruments for Light Measurements, Leo Duval, Sylvania Electric Products, Inc.
November 2—Color and Brightness in Lighting, A. A. Brainerd, Philadelphia Electric Co.
November 9—Design of Factory Lighting I, A. A. Brainerd, Philadelphia Electric Co.
November 16—Design of Factory Lighting II, A. A. Brainerd, Philadelphia Electric Co.
November 30—Field Trip on Factory Lighting, A. A. Brainerd, Philadelphia Electric Co.
December 7—Equipment Design for Factory and Office, P. B. Thorne, General Electric Co.
December 14—Wiring for Lighting and Review, G. E. Shoemaker, Philadelphia Electric Co.
January 4—Design of Store Lighting I, C. C. Shotwell, Philadelphia Electric Co.
January 11—Design of Store Lighting II, C. C. Shotwell, Philadelphia Electric Co.
January 18—Equipment Design for Store Lighting, P. B. Thorne, General Electric Co.
January 25—Field Trip on Store Lighting, C. C. Shotwell, Philadelphia Electric Co.
February 1—Design of Office Lighting I, Robin Adair, Westinghouse Electric Corp.
February 8—Design of Office Lighting II, Robin Adair, Westinghouse Electric Corp.
February 15—Design of School Lighting (Classroom, Auditorium and Stage, Gyms, etc.), Leo Duval, Sylvania Electric Products, Inc.
February 29—Design for Sports Lighting, Leo Duval, Sylvania Electric Products, Inc.
March 7—Field Trip on School and Sports Lighting, Leo Duval, Sylvania Electric Products, Inc.
March 14—Lighting Maintenance and Review, F. J. Vorlander, Champion Lamp Co.

A. A. Brainerd is Course Co-Ordinator and the classes will be held at the Spring Garden Institute, Broad and Spring Garden Streets, Philadelphia. Tuition for the whole series is $25.00.

International Conference on Light To Be Held in Paris

Organization of a conference on light, to be held in Paris September 26 through 30, has been announced by Dr. W. Morikofer, President of the International Committee on Lighting. Principal subject of the meetings will be "Light and Homes." Speakers will report on recent developments in the application of natural daylight and artificial light in homes, physiological and pathological reactions from fluorescent lamps, germicidal lamps and other related subjects.

Although a number of lighting experts from several countries have already submitted reports, applications from others who wish to participate in the Congress will be accepted. Communications should be addressed to Miss Christine Weissenbach, Secretary of the Congress Committee, 6 rue Daubigny, Paris (17°), France.

Summary of Action at Council Executive Meeting

Chateau Frontenac, Quebec City, was the locale on May 9, for the Council Executive Committee meeting. Walter Sturrock, President presided. Present also were: S. G. Hibben, E. M. Strong, Vice-Presidents; A. D. Hinckley, Executive Secretary; Leon Beauchamp, W. P. Beazley, G. F. Dean, R. L. Dennis, W. B. Fulton, C. H. Goddard, F. T. Groome, J. T. Hornsby, D. M. Jones, F. P. Labey, Henry Lushington, W. F. McElman, G. F. Mudgett, W. Pednault, E. Rambusch, J. H. Rylance and George Watters.

Membership Elections

Election of 89 Associate Members and 13 Student Members was reported by the Board of Examiners. Favorable action was taken on the Board's recommendation for the election of 10 full Members. These elections, together with other changes in membership bring the membership figures to those shown in the following tabulation:

September 30, 1950		May 9, 1951
7057	Total Membership	7371
32	Members Emeritus	32*
41	Fellows	42
1610	Members	1704
5005	Associate Members	5310
369	Student Members	282

*Includes 10 Fellows of the Society.

New Committee

President Sturrock referred to discussion at the April 5 Council meeting relative to the appointment of a new committee "Committee on Lighting for Civilian Defense" as an outgrowth of the work of the coordinating Committee on Defense. He noted that because of the urgency of the situation the proposed committee has had one meeting resulting in a restatement of the scope of the committee's work. There was further discussion as to the operation of this committee and as to further representation particularly from the Canadian membership. Following discussion action was taken to recommend to Council an amendment of the approval given on April 5 and to approve for letter ballot of Council the establishment of a Technical Committee on Lighting for Civilian Defense with the following statement of scope:

"To appraise and report on special lighting problems connected with emergency military operation that directly involve civilian defense and protection, such as equipment for bomb shelters, special street and vehicular lighting, mobile self-contained lighting facilities for use in bombed areas, and emergency devices and visual aids to movement in the event of power failure."

Personnel for the committee will be: Lighting for Civilian Defense: L. J. Schrenk, Co-Chairman (Co-Chairman from Canadian Membership pending), J. W. Walsh, Secretary, R. B. Brown, Jr., Harry Grattan, Jr., K. E. Hollingsworth, W. F. Little, Kirk M. Reid, and T. H. Shepherd.

Sustaining Members

The report of the Sustaining Members Committee, submitted for C. C. Shotwell, Chairman, recommended the election of two new members. Favorable action was taken on the election of:

American Steel and Iron Works
5801 South Lowe Avenue
Chicago 21, Illinois
Official Representative: Walter H. Krueger

Powerlite Devices, Limited
1870 Davenport Road
Toronto 9, Ont., Canada
Official Representative: M. B. Hastings

Local Activities

E. M. Strong's report on this activity indicated continuing study of regional boundaries, and review of Guides for Regional V.P.s and the Operation of Regional Conferences.

In this connection, he reported arrangements are underway for eight Conferences next year, dates of which may be available soon.

New Offices

Approval was given to the request of C. A. Atherton, Honorary Secretary of the I.C.I., to sublet part of the Headquarters new offices at 1860 Broadway, for use by the I.C.I. Central Bureau.

Two Cities Install Mercury Street Lighting

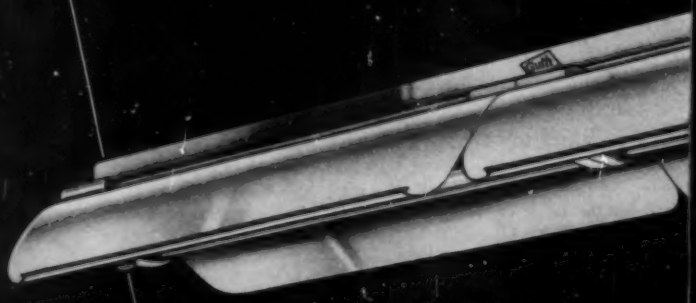
Philadelphia and Seattle have both started street lighting modernization programs, installing mercury-vapor luminaires on through highways.

In Philadelphia, nine miles of streets in south and southwest sections have been newly lighted by 496 mercury-vapor luminaires as the first major step in a 15-year program. The units are equipped with 20,000-lumen lamps and are mounted on 12-foot brackets at a height of 33 feet above street level. The initial illumination level is 1.5 footcandles.

In Seattle a heavily traveled truck highway, the Alaskan Way, has been relighted for 1.4 miles with 20,000-lumen

(Continued on page 13A)

it's all Polar Bear White



for 4′ and 8′ lamps

GUTH WYTE-LINER with AIRFLOW channel

A NEW IDEA FOR BETTER LIGHTING IN FACTORIES

White INSIDE and OUTSIDE . 300 Permalux or PORCELAIN ENAMEL!

- give improved brightness ratios
- take the gloom off the ceiling
- eliminate deep shadows and strong contrasts
- easy to clean—even in coal mines

Guth LIGHTING

THE EDWIN F. GUTH COMPANY / ST. LOUIS 3, MISSOURI

Leaders in Lighting Since 1902

for better sight and better light

Lighting for production to improve precision vision

Avoids gloomy, depressing ceilings with irritating, strong light and shadow contrast. Wyte-Liners spread brightness, cheerfulness, create better seeing and better working conditions.

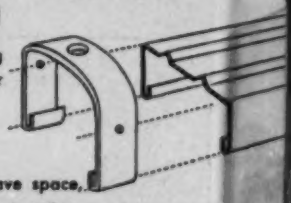
AIRFLOW VENTILATION

provides natural air circulation along entire channel to increase ballast life and efficiency.

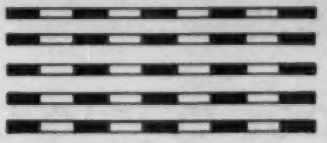
EASY INSTALLATION

wide choice of mounting methods . . . continuous or individual

- *sliding hangers*
- *telescope channels*



interchangeable parts save space, time and money, easy to install



one of many mounting possibilities: alternate fixture and blank space with covered, continuous wire way

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in 2 and 3 40-watt light units, for 4-and 8-ft. Slimline in 4-and 8-ft. lengths.

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are now in production and will be available soon.

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GENERAL ELECTRIC'S Home Light-Conditioning Program is underway in a big way, opening up new opportunities for you.

This sound and practical program brings home lighting into new importance. It gives you a rallying point around which to concentrate your efforts in improving home lighting standards. Since Light-Conditioning is basically a program for conserving eyesight and bettering the comfort and beauty of peoples' homes, it offers tremendous public relations possibilities.

Since the introduction of the Light-Conditioning Program less than a year ago, nearly 100 electric service companies are already tying in. Approximately 2 million Light-Conditioning recipe books have been placed in the hands of the public. And a series of full-color General Electric ads on Light-Conditioning is now appearing in top national magazines. To make the most of the opportunities that Light-Conditioning offers to you, tie in now. Write for full details to Lamp Department, Div. 166-IE-6, General Electric, Nela Park, Cleveland 12, O.

You can put your confidence in—

GENERAL ELECTRIC

(Continued from page 9A)

mercury units, mounted 30 feet above the pavement and spaced 95 feet apart, providing an initial illumination level of 1.8 footcandles. This is the beginning of a $4,000,000 program which will eventually affect more than 330 miles of arteries and highways within the city limits.

Ideas from Other Sections

Have you just been elected as Officer or member of the Board of Managers of your Section? You may be interested in what some of the other Sections and Chapters have found to be successful practice in their operations last year.

Georgia Section, for instance, sends copies of its news releases on meetings to the speakers of the evening. Meeting notices mailed to speakers before the meeting also help them orient themselves to the Section's interests and objectives.

Meeting notices and reports of interesting activities, mailed direct to your own magazine, ILLUMINATING ENGINEERING result in recognition, before the rest of the Society, of your Section's activities. Are awards to be presented at a meeting? Are you sponsoring or co-sponsoring contests, lighting courses, forums, architectural cooperation etc.? Have pictures taken, and send them to the editor of IE. Did your group take part in a successful Conference? Have your publicity chairman write up a report for the magazine.

Invite electrical contractors, architects, consulting engineers, etc. to your meetings. One Section raised its attendance 20% at each meeting by this practice.

If one picture is worth a thousand words, then one inspection trip must be worth ten lectures. At least, many I.E.S. groups have found them so, judging from response to such programs. Some of the more successful ones, though not all by any means, included trips to airports, such as that sponsored by the Southern California Section last winter; and the Georgia Section this spring; the office lighting and maintenance inspection trip which climaxed the Connecticut Section's season; the city-wide tour of outstanding installations made by Milwaukee Section members.

Extension meetings are another phase of this type of program, successfully conducted in a number of Sections. Eastern Pennsylvania Chapter, for example, consists of many small cities and communities. In order to provide service, and promote the I.E.S. cause, for their widely-separated members, this Chapter holds its meetings in different towns, with a local member organizing the proceedings.

INSPECTION trips proved to be successful and popular programs last year. The photo above was taken at the trip sponsored by the Southern California Section, to the Los Angeles Airport.

Attendance at these extension meetings is considerable.

The Western Michigan Chapter in Grand Rapids has also found extension meetings in nearby towns a good method of extending their Chapter's activities.

A number of Sections and Chapters devote space on their meeting notices to local I.E.S. news. Reminder dates of meetings still to come, have also been incorporated on meeting notices, as well as national Society notices such as deadlines for payment of dues, what to do if you go into the armed services, etc.

Joint meetings are hardly new, but are invariably of value. Among the more different co-sponsors of such I.E.S. meetings, however, have been joint meetings with local Optometric societies, safety engineers, safety councils, electrical distributors, etc.

How to show more honor and appreciation to past chairmen has been under study by several groups. Certificates, presentation of lapel pins, etc. have been practiced by some. Southwestern Section honored its past chairmen last winter with an "Old Timers Night" — a meeting planned specially to honor the men whose efforts established and continued their Section, and a review of achievements.

Full scale conferences, quite aside from Regional Conferences, have been conducted in some parts of the I.E.S. structure. Iowa Section's conferences are especially impressive and successful. They feature four full-day conferences each year, in addition to their regular programs, attracting attendance from all over the state.

An appropriate door prize pops up meetings in some Sections. Prizes have consisted of I.E.S. pins, Lighting Handbooks, subscriptions to Data Sheets. Especially at dinner meetings, the dinner ticket entitles each holder to a chance on the prize drawing.

"My Most Interesting Job" Contests continue in popularity. Additional recognition to the Section and the individual member is gained when winning installations are published in IE.

Timely "clinics" have been a valuable service to members. Both the Chicago Section and the Cleveland Section, for instance, have sponsored phenomenally successful clinics on Protective Lighting, providing an outstanding service to their communities.

Residence Lighting Forums are growing. Four Sections have flourishing Forums — New York, Detroit, Atlanta and Chicago — with a fifth group in Knoxville, Tenn. about to draw up its By-Laws. Worthwhile lighting activities are carried on by these groups, including eight meetings per month (each), lighting courses and educational work with decorators.

Lighting and the Nation's Welfare

This is the title of a new pamphlet just off the press, prepared as a public service by the National Information Committee on Lighting. The book summarizes vital present-day services of illumination to American industrial production, public safety, research and education, and in government.

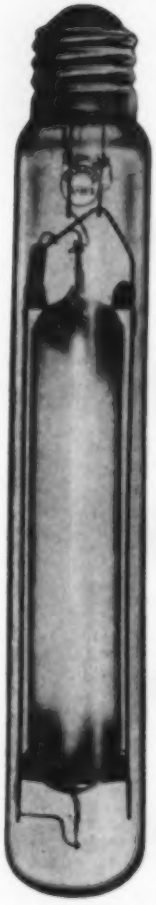
In addition to statistics on the effects of lighting in five phases — Production Lighting, Office Lighting, Protective Lighting, Public Safety, Education

(Continued on page 15A)

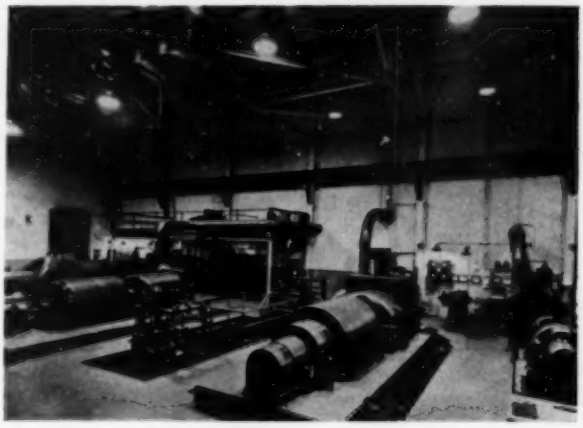
HANOVIA *HIGH PRESSURE*
MERCURY VAPOR LAMPS

FOR

INDUSTRIAL LIGHTING (MEDIUM AND HIGH BAY)
STREET LIGHTING • FACTORY AND RAILROAD YARDS
POWER HOUSES • GAS STATIONS
INDOOR AND OUTDOOR SPORT ARENAS, ETC.



- **MOST ECONOMICAL**
- **HIGHER LIGHT OUTPUT**
- **LONGER LAMP LIFE**
- **FEWER LAMPS NEEDED**
- **REDUCED MAINTENANCE COSTS**



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TYPE H LAMP DIVISION
100 CHESTNUT STREET, NEWARK 5, N. J.

(Continued from page 13A)

Lighting—the report includes charts and graphs illustrating points brought out by the study.

The report "Lighting and the Nation's Welfare" is available at 15 cents per copy in quantities of 100, 10 cents per copy in lots of 500 or more. Single copies are 25 cents each. Requests should be addressed to: National Information Committee on Lighting, 1410 Terminal Tower, Cleveland, Ohio.

Street Lighting Conference Featured in Cleveland

A two-day street lighting conference was conducted May 8 and 9 at the General Electric Lighting Institute, Nela Park, Cleveland, featuring latest discussions on blackout, lighting for security, and the relation of street lighting to the nation's mobilization program. More than 175 of the country's leading street lighting experts attended.

Chief speaker was Luther D. Shank, of Washington, D. C., in charge of street lighting material allocations for the National Production Authority. He presented the government's official stand regarding the position of street and highway illumination in the nation's mobilization program.

Other speakers included Fred D. Crowther, of G.E.'s Lighting and Rectifier Divisions at Lynn, Mass., who spoke on "Street Lighting in a Mobilization Economy," and Kirk M. Reid, illuminating engineer in charge of street lighting at Nela Park, who discussed "Are Blackouts and Dimouts in Prospect?" Reid had just returned from Washington, where he put this question to government authorities.

Another paper of wide interest was "Night Accident Rates as Affected by Improved Street Lighting," by Frank Wyatt, electrical engineer of the Chicago Park District.

The final afternoon of the program was devoted to an open forum, at which utility and municipal experts exchanged information and related their experiences in the street lighting field.

PRESIDENT'S NIGHT dinner at the Georgia Section I.E.S., was attended by over 100 members and guests from all over the South. Shown here are the speakers and some of the officers of the Section. Front row, l. to r., Walter Sturrock, National President, who completed his tour of the country by addressing this meeting; Harold M. Horton, chairman, Georgia Section; Alston Rogers, chairman, I.E.S. Committee on Progress. Back row, James P. Whitehead, Jr.; J. E. Sweatte, chairman, Membership Committee of the Section; and Judd Lough, of the Board of Managers of the Section. Mr. Sturrock was presented with a leather writing kit by Joe B. Browder, vice-president of the Southern Region.

"Street Lighting" Magazine Makes Its Debut

A new magazine, *Street Lighting*, will be published quarterly by the National Street and Traffic Safety Lighting Bureau, 1410 Terminal Tower, Cleveland, Ohio. The magazine is edited especially for those officials responsible for planning, installing and maintaining the lighting on the nation's streets and highways.

Edmond C. Powers and David Skylar, both of the Griswold-Eshleman Co., are Editor and Associate Editor, respectively. Mr. Powers is also Director of Public Information of the Bureau.

Lighting Mobilization Center Is Opened

A "Lighting Mobilization Center," designed to demonstrate how lighting affects seeing, improves visibility of the seeing task and creates pleasant environments for workers, was unveiled May 2, at Nela Park by General Electric's Lamp Department.

The new center is said to have assembled at one focal point all the demonstrations of seeing and lighting essential to the nation-wide industrial mobilization activities. Each wall of the room serves as an individual display and separate "theater of action." The ceiling is designed to show many different types of lighting for high illumination levels for industry.

The center was developed by a planning committee headed by C. M. Cutler, illuminating engineer in charge of industrial and store lighting for the engineering division of General Electric's Lamp Department.

New Issue of ECPD Guidance Manual Published

A guidance manual intended for engineers who are aiding young men interested in the engineering profession was recently published by the Engineers' Council for Professional Development, New York, N. Y. The 15-page pamphlet, prepared by the ECPD Guidance Committee, urges members of local engineering societies and sections and chapters of national engineering societies to establish guidance committees to aid high school pupils to determine whether they are qualified for careers in engineering. The present critical engineering manpower shortage emphasizes the need for guidance of the type indicated in this manual.

(Continued on page 18A)

CURTIS

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Write for information about the Curtis Light and Sound Conditioning System's unlimited applications.

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(*Continued from page 15A*)

The manual explains briefly how to organize advisory committees and how to select committee members. The manual contains suggestions for working with high schools and secondary school students and lists aids especially useful in counseling high school boys.

The guidance manual is supplemented by an appendix, "Shall I Study Engineering?" which is a questionnaire to be filled out by the student for use of the engineer who is advising him.

Copies of the manual with questionnaire may be obtained from ECPD, 29 West 39th Street, New York 18, N. Y. Price of combination, 20 cents. Cost of manual purchased separately 15 cents. The price of the questionnaire, ten cents. A deduction of 25 per cent for purchase of 25 or more is allowed.

Prize Contest Awards Made For Philadelphia Contractors

Results of the Electrical Contractors Planned Lighting Prize Award Contest, given in conjunction with the Electrical Association of Philadelphia, were announced at the April 24 meeting of the Philadelphia Section, I.E.S.

The winner of the silver plaque, awarded to the contracting company which performed the outstanding job on both individual awards and leads on lighting prospects, was the Independent Wiring Co., Inc. of Philadelphia.

Sixteen cash prizes are presented for commercial, industrial and exterior installations. Jobs eligible for prize awards and plaque competition must be within the geographic territory covered by the Electrical Association of Philadelphia, include only those where the contractor has worked cooperatively with a representative of Philadelphia Electric Co.

SILVER PLAQUE is presented to Milton W. Stratton, vice-president and chief engineer of Independent Wiring Co., Inc., by John A. Morrison, managing director, Electrical Association of Philadelphia, as Sylvan W. Drucker, president of the winning firm, watches. The plaque was awarded for the outstanding job in the Philadelphia area for cooperation of wholesaler, contractor and utility men. Presentation took place at the April 24 meeting of the Philadelphia Section I.E.S.

IT SEEMS TO ME

Tunnel Exits

To the Editor:

Judging by the answers to my discussion on the paper, "Effective Practice in Lighting Unusual Hazardous or Irregular Roadway Areas" by Swetland and Lindsay, it appears that I did not make myself clear in stating the problem which I believe required attention. That problem concerned the reduction of sky brightness at tunnel exits. The authors answered my discussion by saying that they had had no experience of "hazardous loss of visibility upon leaving these tunnel portals."

The problem should be — the contrast brightness between sky and side walls of a tunnel *before* leaving the tunnel. This condition extends back into some tunnels as much as three hundred feet or four hundred feet. True enough, the condition only affects those tunnels which do have an exposure of sky back into the tunnel, and it may be also true that there are not many tunnels with this condition.

It is my contention that it would be practically uneconomical and unfeasible to provide enough artificial illumination near the exists of these tunnels to counteract extreme contrast between sky brightness and the dark interior of a tunnel.

That was why I sought for another solution to this problem, and found it already in existence at the opposite end of the tunnel mentioned in my discussion, namely, the Funston Tunnel in the Presidio in San Francisco. This tunnel has now been refinished in a flat almost white heavy hard paint that is supposed to eliminate the roughness of the natural finish concrete, as well as diffuse the existing mercury vapor light. This refinish job has been completed approximately three weeks, and already there is a heavy coat of diesel and gas exhaust fumes which will make it dark in a short while. The State Highway Department is interested in better visibility because of accidents that have happened in the tunnel, and they are investigating the possibility of screening this sky brightness.

One other item which the authors, I believe missed, was that this is a two-way tunnel, not a one-way tunnel, and therefore, it is impossible to project daylight by means of some modified heliostat reflecting surface. Such a procedure would be possible in a one-way tunnel, but to direct sunlight into the opening of a two-way tunnel by means of specular surfaces would be difficult, if not impracticable.—G. A. Trosper, *Illuminating Engineer, Pacific Gas & Electric Company, San Francisco, Calif.*

OBITUARY

E. W. Fowler, member of the Illuminating Engineering Society since 1935, died May 1. Mr. Fowler had been active in I.E.S. work and had served upon many committees of the Society.

He was recipient of the first Niagara Award, which was bestowed on him for

E. W. Fowler

his paper, co-authored with C. L. Crouch, on "Glare and Lighting Design." Mr. Fowler served on the Committee on Papers from 1945 to 1947 and was Chairman in 1947 and 1948.

Secretary and later Chairman of the Western New York Section, Mr. Fowler was greatly respected in his section and by the Society for his many efforts for forwarding the objectives of I.E.S. Among them any other positions which he held are the Chairman, Sub-Committee on Lighting Data Sheets of the Lighting Service Forum; member, Office Lighting Committee, Committee on Street and Highway Lighting and the Committee on Lighting Study Projects in Industry.

Interesting Installations in the Carolinas

Installation	Address	Type of Lighting
North Carolina		
Cooperative Savings & Loan	Wilmington	Fluorescent cove
Cinderella Booterie	Wilmington	Fluorescent and incandescent recessed
Sally Frocks	Wilmington	Fluorescent and incandescent recessed and cove
My-Shop	Wilmington	Fluorescent and spots, surface and cove
Tide Water Power Co. Bldg.	Wilmington	Fluorescent and incandescent — surface, recessed and cove
Ellis Store Co.	Greensboro	Louverall
White Oak Mills of Cone Mills Corp.	Greensboro	Fluorescent industrial
Library at Woman's College, University of N. C.	Greensboro	Louverall and fluorescent troffers
Wright's Clothiers	Greensboro	Louverall
Duke Power Co.	Greensboro	Fluorescent troffers
S & W Cafeteria	Greensboro	Cove
Asheboro Hosiery Mills	Asheboro	Fluorescent industrial
Duke Power Co.	Burlington	Fluorescent
Mace's Jewelry Co.	Reidsville	Louverall and incandescent (wooden louverall section—6" x 6" x 6" cells)
South Carolina		
Haltiwanger's Ladies' Ready-To-Wear	Columbia	Louverall in color in sales area
Belk's Department Store	Columbia	Window lighting—recessed fluorescent and incandescent
Hamilton's Jewelry Store	Columbia	Recessed fluorescent and incandescent in sales area
Carolina Life Building*	Columbia	Specially designed recessed fluorescent office lighting. Cove lobby lighting.
Palmetto State Life Bldg.	Columbia	Recessed fluorescent office lighting, slimline troffers.

*It is of interest to the engineer to know that the building has a complete triple floor duct system, that the luminaires are controlled by a low-voltage control system with switches located on walls. Control line is installed in floor duct with parallel control at various desks.

Compiled by Local Representatives of Wilmington and Greensboro, North Carolina and Columbia, South Carolina.

ABOUT PEOPLE

J. L. Busey was elected to the Board of Governors of the National Electrical Manufacturers Association at its March 13th meeting. Mr Busey, vice-president, General Electric Co., will serve for the rest of the term of E. E. Potter.

Donald I. Bohn, chief engineer for the Aluminum Co. of America, has been awarded the Lamme Medal, annual award for high achievements in the development of electric apparatus or machinery.

The National Production Authority, U. S. Department of Commerce has appointed **Berlon C. Cooper,** Eastern Editor of *Electrical Construction and Maintenance,* as Consultant in the Building Materials Division of NPA's Facilities and Construction Bureau.

Gordon E. Walter has been appointed assistant division engineer of General Electric's Specialty Transformer Engineering Division at Fort Wayne, Ind.

Dr. Arthur W. Wishart, vice-president of the McKee Glass Co., Jeanette, Pa., has joined Westinghouse Electric as manager of a newly-organized Glass Manufacturing Division. Dr. Wishart will make his headquarters at the glass plant in Fairmont, W. Va., which will be one of the glass factories under his direction.

Don G. Mitchell, president, Sylvania Electric Products, Inc., accepted the 1950 Howard G. Ford Award for his company's achievements in growth of sales during 1950. The award is given annually by the Sales Managers' Association of Philadelphia for contributions to the improvement in distribution.

The retirement of **Harold L. Olesen,** executive assistant, Weston Electrical Instrument Corp., has been announced. Mr. Olesen has been with Weston for 20 years.

The first prize winners of a competition sponsored by the American Institute of Electrical Engineers have been announced. They are **C. P. Hayes** and **H. G. Gould** of General Electric's Small Apparatus Division and Ballast Engineering Division, respectively. Their winning paper was on "Noise Evaluation of Fluorescent Lamp Ballasts."

Charles E. Scholl, formerly with the Bright Light Reflector Co., Bridgeport, Conn., has resigned from that company to accept a post of General Sales Manager of the Fast-Lok Manufacturing Co., Bridgeport.

Russell J. Dickason, formerly local representative and faculty advisor to the student branch of I.E.S. at the University of Cincinnati, has taken a position as electrical engineer at the General Electric Company, Cleveland.

BOOKS AND PAMPHLETS

Index to Military Purchasing Offices, a guide to industry in selling to the military departments, has been revised and issued by the Munitions Board. Listing commodities under 35 major categories, the booklet is cross-indexed to indicate the appropriate purchasing office for any item. Copies should be requested from Central Military Procurement Information Office, Munitions Board, Department of Defense, The Pentagon, Washington 25, D. C.

Publication of a new weekly **Controls Service,** indexing and digesting the welter of new price, production and distribution regulations, has just been inaugurated by the *Journal of Commerce.* This service consists of Master Editions of all-inclusive "Controls Guide" at six-week intervals, and weekly "Bulletin Summaries" designed to keep each edition constantly up-to-date. The newest Master Edition has just been issued, containing an Index showing the restrictions now in effect on 1,697 different products and services, and the digest of 82 control regulations and their amendments. A time-table outlining "What's Ahead in Controls" is also included on a range of 32 product groups. Subscriptions to this weekly Controls Service may be had at $25 per year from the New York Journal of Commerce, 63 Park Row, New York 15, N. Y. Master Editions of the "Controls Guide" are one dollar each.

NEW MEMBERS

At the meeting of the Council Executive Committee held in Quebec, Canada on May 9, 1951, the following were elected to membership:

British Columbia Section

Members:
Ashbee, H. J., Amalgamated Electric Corp., Ltd., Vancouver, B. C.
Jones, A. A., Vancouver Lighting Supply Co., Ltd., Vancouver, B. C.
Associate Members:
Smith, L. S., Amalgamated Electric Corp., Ltd., Vancouver, B. C.
Sutton, W. G., Amalgamated Electric Corp., Ltd., Vancouver, B. C.

Capital Section

Associate Member:
Tate, R. W., 4432 Que St., N. W., Washington, D. C.

Carolinas Chapter

Associate Members:
Ayers, J. T., Johannesen Electric Co., Greensboro, N. C.
Carrington, R. G., Graybar Electric Co., Charlotte, N. C.
Daniel, R. E., Johannesen Electric Co., Inc., Greensboro, N. C.
Mason, C. Q., Greenville Textile Supply Co., Greenville, S. C.
Parks, B. B., 206 Wallace Bldg., Greenville, S. C.
Ward, W. D., Noland Co., Winston Salem, N. C.
Witbeck, J. M., Crouse-Hinds Co., Charlotte, N. C.

Central New York Chapter

Associate Member:
Meade, R. E., N. Y. State Electric & Gas Co., Oneonta, N. Y.

Chicago Section

Member:
LeBold, W. K., Room 121, Navy Pier, Chicago, Ill.
Associate Members:
Bernd, F. J., Curtis lighting, Inc., Chicago, Ill.
Cronin, T. G., Sylvania Electric Products, Inc., Chicago, Ill.
Hansman, E. J., General Electric Co., Chicago, Ill.
Lozano, Edmund, Chicago Park District, Chicago, Ill.
Student Member:
Duster, C. E., University of Illinois, Urbana, Ill.

Cleveland Section

Associate Members:
Greenland, A. L., Wagner Green Co., Cleveland, Ohio
Hilscher, R. C., 519 4th St., N. W., Canton, Ohio
Kyle, C. H., Babcock & Wilcox, Barberton, Ohio
Student Members:
Bednar, C. M., Case Institute of Technology, Cleveland, Ohio
Braun, A. R., Case Institute of Technology, Cleveland, Ohio
Cronlger, J. D., Case Institute of Technology, Cleveland, Ohio

Connecticut Section

Associate Members:
MacLafferty, T. J., General Electric Supply Corp., Bridgeport, Conn.
Zitomer, J. H., Hi-Lite Fluorescent Mfg. Co., New Haven, Conn.
Zona, P. V., United Mfg. Co., New Haven, Conn.

Cornhusker Chapter

Associate Members:
Amato, L. A., 414 Main St., Plattsmouth, Nebr.
Bates, T. H., Westinghouse Electric Corp., Omaha, Nebr.
Brown, E. I., Knapp-Spencer Co., Sioux City, Iowa
Getman, G. N., Luverne, Minn.
Getman, M. W., 210 Francis Bldg., Sioux City, Iowa
Grimes, W. B., General Electric Co., Omaha, Nebr.
Hatch, Dick, Archer Electric Co., Omaha, Nebr.
Nyreen, C. W., Nystrom Electric Co., Sioux City, Iowa
Shoning, D. W., Westinghouse Electric Supply Co., Sioux City, Iowa

Eastern Pennsylvania Chapter

Member:
McCulloch, J. H., 200 N. Prince St., Shippensburg, Pa.

Florida Chapter

Associate Members:
Bronsvel, R. C., Route 8, Box 299A, Jacksonville, Fla.
McCormick, C. E., Raybro Electric Supplies Inc., Tampa, Fla.

Foreign Non-Section

Associate Members:
Stewart, J. C., Claude Neon Lights (S. A.), Ltd., Johannesburg, South Africa
Van Nostrand, Mrs. Beatrice B., 239 Merchant, Honolulu, Hawaii
Student Member:
Sahab, Mohammed, 2 Mohamed Pasha Sidky St., Midan El Falaki, Cairo, Egypt

Georgia Section

Associate Members:
Boynton, E. M., The Electric Supply Co., Atlanta, Ga.
DeFreese, Frank, Planned Lighting Co., Decatur, Ga.
Robinson, L. P., Sylvania Electric Products Inc., Birmingham, Ala.
Russell, J. M., Lithonia Lighting Products Co., Lithonia, Ga.
Willis, R. C., Tennessee Valley Authority, Wilson Dam, Ala.

Heart of America Section

Member:
Stiers, W. L., Sylvania Electric Products Inc., Kansas City, Mo.
Associate Member:
Kobrock, C. H., Kansas City Terminal Railway Co., Kansas City, Mo.

Indiana Chapter

Associate Member:
Weir, D. E., Allen & Kelley, Indianapolis, Ind.

Iowa Section

Associate Member:
Graham, D. M., Gibson Mfg. Co., Waterloo, Iowa
Student Member:
Gibson, V. P., 828 Hanna, Waterloo, Iowa

Maritime Chapter

Associate Member:
Dickson, T. H., Canadian National Railways, Moncton, N. B.

Mexico Chapter

Member:
Sanvicente, G., Federal District Government, Departamento del Distrito Federal, Mexico D. F., Mexico

Michigan Section

Associate Members:
Fletcher, C. H., *Jr.*, Westinghouse Electric Corp., Detroit, Mich.
Henson, A. R., S. P. Ecclestone & Sons, Inc., Detroit, Mich.
Holbrook, T. L., Westinghouse Electric Corp., Detroit, Mich.
Snyder, G. G., Crouse-Hinds Co., Detroit, Mich.

Milwaukee Section

Member:
Avery, B. F., General Electric Co., Milwaukee, Wis.
Associate Members:
Allen, A. A., Westinghouse Electric Supply Co., Green Bay, Wis.
Kuehl, R. J., Allis Chalmers Mfg. Co., Milwaukee, Wis.
Wilke, E. W., Westinghouse Electric Supply Co., Wausau, Wis.
Student Member:
Grotelueschen, O. H., 336 Wisconsin Ave., Sheboygan, Wis.

Mississippi Chapter

Associate Members:
Huntley, W. W., Mississippi Power & Light Co., Jackson, Miss.
Watkins, Leigh, III, Mississippi Power & Light Co., Jackson, Miss.

Montreal Section

Members:
Doucet, B. C., Curtis Lighting of Canada Ltd., Montreal, Que.
Haacke, E. M., J. A. Wilson Lighting & Display Ltd., Montreal, Que.
Tate, R. S., Canadian General Electric Co., Ltd., Montreal, Que.

Mother Lode Chapter

Associate Member:
Lerrero, N. J., Pacific Telephone & Telegraph Co., Sacramento, Calif.

New England Section

Associate Members:
Kirby, P. E., Westinghouse Electric Corp., Belmont, Mass.
Wolfe, R. J., General Electric Co., Boston, Mass.

(Continued on page 29A)

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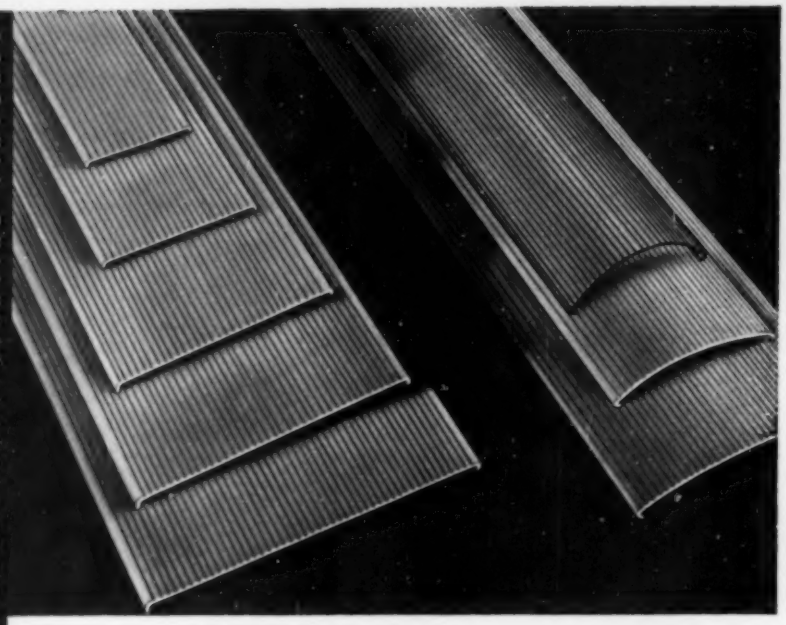

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This Georgia Library was Designed with "Seeing" in Mind

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IT'S EASY TO SEE WHEN IT'S

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JOB: F. W. Rogers Co., Lynn, Massachusetts.
ARCHITECT: H. E. Davidson & Son, Boston, Massachusetts.
LIGHTING ENGINEER: J. Robert Cornell, Lynn Gas & Electric Co., Lynn.
SUPPLIER: DesRoberts Electric Supply Co., Lynn.
FIXTURES: 14o. 3224 two lamp recessed fixtures, with diffusing glass, on 10' spacing.
INSTALLATION DATE: July, 1946.
INTENSITY: Average on counters — 38 Footcandles in service. Average throughout area — 31 Footcandles in service.

Can you guess the date of this lighting installation?

Don't feel too badly if you fail in this "guess-test." Not many would know that these modern-as-tomorrow LITECONTROL fixtures were installed in July, 1946 — *five years ago!*

As you can see, the years of continuous use in this up-to-date department store have exacted no toll—either in appearance or performance—from these clean-lined, functional No. 3224 Troffer Type Recessed Units.

What's more, in addition to the proven feature of dependable long life, this unit is outstanding for easy access and low maintenance cost.

On *your* next lighting job, prove for yourself—as so many others have profitably been doing for years—that it pays to save with LITECONTROL . . . in time, in efficiency, in money.

Call in your LITECONTROL Representative. No obligation, of course.

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PUBLICATIONS *of the*
ILLUMINATING ENGINEERING SOCIETY

These publications summarize the studies and conclusions of technical committees of the Illuminating Engineering Society over a period of years. They contain the latest available information about many aspects of the art and science of illumination, and include details of application as well as lighting technique. Each publication listed here carries the authority and approval of the Society.

These Society publications are available in single copies for information and for lighting reference book shelves or in quantity for educational or other distribution. Each publication is numbered for ordering when using the coupon printed on the back of this page.

(1) I.E.S. LIGHTING HANDBOOK

One volume, 850 pages. A complete reference guide providing basic information on all phases of lighting. For architects, designers, engineers and others who plan, install and manufacture lighting systems and equipment. $7.50 per copy; $5 in lots of 10 or more.

I.E.S. Members who have not availed themselves of the privilege of one membership copy at $5 may still do so. Add 50c if for shipment abroad.

(See Page 8A)

I.E.S. APPROVED LIGHTING PRACTICES

These booklets contain the latest official I.E.S. lighting recommendations; illustrated with charts, sketches and photographs.

(2) HOME LIGHTING Recommended Practice (1947)

(3) OFFICE LIGHTING Recommended Practice (1947)

(4) STREET AND HIGHWAY LIGHTING American Standard Practice (1947)

(5) LIGHTING PRACTICES FOR STORES AND OTHER MERCHANDISING AREAS (1946)

(6) SCHOOL LIGHTING American Standard Practice (1948)

(7) LIBRARY LIGHTING Recommended Practice (1950)

(8) DAYLIGHTING Recommended Practice (1950)

Booklets above available at 50 cents per copy or in quantity as follows: first 4 copies, 50c each; next 20, 25c each; all over 24 copies, 15c each.

(9) INDUSTRIAL LIGHTING American Recommended Practice (1942)

First 10 copies, 25c each; next 40, 20c each; all over 50 copies, 15c each.

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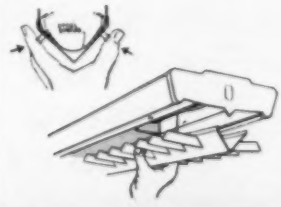

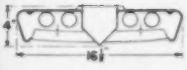

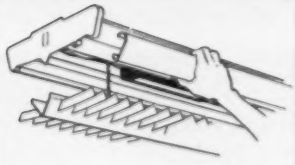

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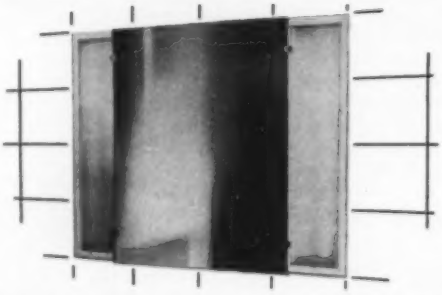

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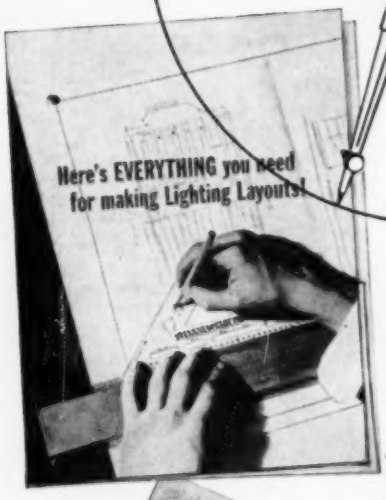

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